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AUTOMATIC DATA PROCESSING SYSTEM STUDY FOR MASSACHUSETTS GENERAL HOSPITAL DIAGNOSTIC RADIOLOGY DEPARTMENT

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FOREWORD

The Bureau of Radiological Health implements a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

Within the Bureau, the Division of Medical Radiation Exposure deals with 1) the reduction of unproductive ionizing radiation exposure of patients, workers, and others exposed by the use of x-rays and other machine-produced ionizing radiation, radioactive materials and radiopharmaceuticals, and 2) the improvement of radiological "systems" and methodology in the healing arts.

The Bureau publishes its findings in Radiological Health Data and Reports (a monthly publication), Public Health Service numbered reports, appropriate scientific journals, and technical report series for the Bureau's divisions, offices, and laboratories.

The technical reports of the Division of Medical Radiation Exposure allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are also included in the collections of the Library of Congress and the Clearinghouse for Federal Scientific and Technical Information.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

Because of the specialized nature of this report, initial distribution is being made only to hospital radiology residency programs. Additional copies may be purchased from the Clearinghouse for Federal Scientific and Technical Information (see ordering information on inside front cover).

John C. Villforth

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The Division of Medical Radiation Exposure is engaged in projects and studies aimed at assessing and minimizing radiation exposure in the healing arts and increasing the efficient utilization of radiological services in clinical practice. Several of these efforts involve the application of systems analysis and information and communication techniques to critical functions within a hospital environment.

This report documents current practices in the diagnostic radiology department of a large general hospital. Problem areas are identified and revised procedures including automated techniques are recommended as a means to greater efficiency in storage and retrieval of radiographic jackets, creation and transmittal of diagnostic x-ray reports, and scheduling of patient procedures. The implementation of such recommendations by medical centers could result in a substantial reduction of unproductive x-ray examinations on a national basis. A network of similar systems could also provide data on the x-ray experience of patients in a form which would meet the Bureau's needs for current information on trends in radiology practice and population exposure.

Arve H. Dahl
Acting Director
Division of Medical Radiation Exposure
Bureau of Radiological Health

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SECTION 1

INTRODUCTION AND SUMMARY

This report describes a study of the Massachusetts General Hospital (MGH) Diagnostic Radiology department, performed under contract to MGH by the Honeywell Systems and Research Division, Research Department, and supported in part by the Honeywell Advanced Communications Systems group and the Bureau of Radiological Health. The primary goal of the study was to define how the operating effectiveness and efficiency of MGH Diagnostic Radiology can be increased through the application of advanced communications techniques.

The effort required a systems study of the present operating methods of MGH Diagnostic Radiology, followed by the conceptual development of systems to aid in X-ray patient scheduling, X-ray film filing and retrieval, and the reporting of diagnostic X-rays results. These concepts were based on the use of computers and advanced communication methods to aid the efficient flow of patient data and reports both internal to and outside the Radiology department. The concepts have use not only in the provision of better patient care but in the research and teaching aspects of department operation.

The phrase "systems study" can be interpreted in many different ways. Honeywell's systems approach to MGH Radiology involved a detailed examination of:

- The qualitative and quantitative aspects of overall department operation
- The requirements of the radiological process
- The inputs to and outputs from the department, as defined by the requirements
- How the inputs are generated and operated upon
- How the outputs are processed and used, both within MGH Radiology and external to it, in the total hospital environment
- The prevailing efficiency and effectiveness in performing various subfunctions within the department, such as X-ray patient scheduling, film filing, and diagnostic reporting

JH-2

Examination of these factors furnished the necessary background for the conceptual development of a radiology system for MGH incorporating scheduling, filing and reporting functions. This system is discussed in detail in the report.

Section 2 sets the scene with a general description of the Massachusetts General Hospital environment. It reviews the structure and general goals of MGH Radiology as well as the problems faced by the department -- problems which are common to many institutions similar to MGH in size and nature.

The diagnostic X-ray process, as it existed at the time of the on-site data gathering effort, is described in Section 3. The narrative descriptions are complex, due to the nature of the subject; because of this, the data is also presented in the form of block flow diagrams and process sequence narrations (Appendix B).

Section 4 discusses the requirements which must be met in moving a patient through Diagnostic Radiology, indicating the nature of the information and information flow inherent in the process. Section 5 is a critical discussion of the manner in which MGH meets these requirements. It also points out areas where the application of automatic data processing techniques promises significant benefits in terms of increased efficiencies throughout the system.

Sections 6 and 7 present subsystem alternatives for the scheduling, film file and diagnostic reporting functions, with each alternative incorporating a different level of sophistication in automated information handling. Section 7 presents a detailed review and discussion of six generic concepts of diagnostic X-ray reporting methods, some of which are being investigated on an experimental basis by various radiologists throughout the country. These are critically evaluated, and one is recommended for development and implementation; this reporting method has been given the name DITRIDE. After a consideration of various system alternatives (Appendix H), a total system was defined and recommended. It is described in Section 8.

Section 9 is a summary of recommendations which evolved from the MGH Diagnostic Radiology study. These include:

- Development and implementation of the recommended total system

- Modifications of the present organizational structure of the Radiology Department and formalized recognition of same

- Continuation of data gathering on patient examination times, to aid present patient scheduling procedures and to provide a data base for automated scheduling.

Much of the data gathered during the study is presented in Appendixes A through G. It represents conditions as they were encountered during the on-site data gathering phase of the study (December 1968 - February 1969).

Appendixes H and I discuss total system alternatives and the tradeoffs associated with each. Appendixes J and K present further detail on several of the reporting methods discussed in Section 7, with J treating at length the syntax analysis required for DITRIDE.

SECTION 2
BACKGROUND

2.1 MASSACHUSETTS GENERAL HOSPITAL

Massachusetts General Hospital may be characterized as a private, incorporated institution supported by voluntary contributions and receipts from patients. One of its primary functions is the care of acutely ill persons or such chronic cases as can be substantially relieved by hospitalization of short duration.

The hospital consists of three main divisions:

- General Hospital, which is mainly for patients unable to afford the cost of private medical care and which includes the Out-patient Clinics and the Emergency Ward, where any person injured by accident or overcome by acute illness may be received
- Baker Memorial division, which houses patients that have been referred by a private physician in private or semi-private accommodations
- Phillips House, which has only private facilities, for patients who prefer a greater degree of personalized service in their medical care

The MGH Corporation consists of 105 members of which 4 officers and 16 members, comprising the board of trustees, serve as the governing board. The trustees are also members of various standing committees, composed solely of trustees, as well as of combined committees of both trustees and hospital staff.

2.1.1 Administration

The hospital administration is made up of a general director, an administrative committee, deputy directors, and executive and administrative assistants. There are directors or administrative assistants for the General Hospital, Baker Memorial, Phillips House, MGH Clinics, and Nursing Service, as well as directors of departments and unit directors.

2.1.2 Professional Staff

The professional staff of the hospital is composed of (a) the general director, (b) the general executive committee, (c) a chief of service or department, (d) physicians, (e) associate physicians, (f) assistant physicians, (g) assistants, clinical associates, and clinical assistants for the particular division or department, and (h) various staff members with special-purpose activities related to the particular service or department. Table 1 shows a breakdown of the staff and includes visiting, consulting visiting, and associate visiting staff. In addition, there are 202 residents and interns, and 306 clinical and research fellows. These figures do not include the staff of the McLean Hospital or the Massachusetts Eye and Ear Infirmary.

2.2 STRUCTURE OF MGH RADIOLOGY

2.2.1 Functional Grouping, Geography, and Organization

In accordance with the overall structure of the hospital and its division of service as to general socio-economic groups (General Hospital, Baker Memorial, and Phillips House), the Radiology department is similarly structured. Radiological services exist in the White Building (General Hospital), in Baker Memorial, and in Phillips House, with the services falling into the following categories:

- White Building:

White-1 (W1) Radiology:	Emergency ward patients
White-2 (W2) Radiology:	Clinic outpatients and General Hospital inpatients

- Baker Memorial:

Baker-1 (B1) Radiology:	Private ambulatory patients
Baker-2 (B2) Radiology:	Private inpatients

- Phillips House:

Phillips House (PH) Radiology:	Private inpatients

The presently existing organizational structure of the total department is not highly formalized. There are 22 radiologists on the professional staff serving the Diagnostic Radiology section; other personnel are shown in Table 2. For the purpose of separating Diagnostic Radiology in terms of functional organization from the total department, the chart shown in Figure 1 was constructed.

Table 1. Numbers of Professional Staff -- MGH*

Area	Staff	
	Regular	Visiting
Medical Division		
General Medicine	153	2
Dermatology	37	-
Neurology	36	-
Psychiatry	75	-
Children's Service	80	-
Surgical Division		
General Surgery	51	22
Gynecology**	3	-
Neurosurgery	15	2
Orthopedic Surgery	32	6
Urology	7	3
Oral Surgery	12	18
Departments		
Pathology	27	-
Anesthesia	25	-
Biochemical Research	6	2
Bacteriology	3	-
Clinical and Clinical Chemistry Labs	2	-
Radiology	37	2
Physical Medicine	1	-
Blood Bank and Transfusion	2	-
Totals	604	57

*154th Annual Report of the Trustees of MGH - 1968

**Rest of staff shared with General Medicine and Surgical Services

Table 2. Radiology Personnel*

Job Title	Department (all shifts)							Totals
	W1	W2	B1	B2	PH	GH**	BH**	
Clerk		16 (4 PT)†	1	3 (2PT)	3 (2PT)			23 (8PT)
File			1			2		3
Senior		2						2
Receptionist	(1 PT)		1					2 (1PT)
Clerk-Typist	1	1		1				3
Secretary								
Executive					1			1
Senior	1	1	1	1	1			5
Medical	5 (3PT)	17 (6PT)	1	6 (3PT)	2			31 (12PT)
Office Assistant		5						5
Executive				1		1		2
Senior		2	1	1				4
Dark Room Tech.		5	1	2		1		9
Head		1						1
Non-Nurse Tech.	3	25 (1PT)	1	5	1	5	2	42 (1PT)
Chief						1		1
Asst. Chief	1	2						3
Head	1			1	1		1	4
Portables								3
Fluoro Aide		3	3	2	1			9

*From Personnel Cardex file, January 1969; does not include student technologists.

**GH = General House, BH = Baker House

†16 (4PT) indicates that, of a total of 16 clerks, 4 are part-time employees

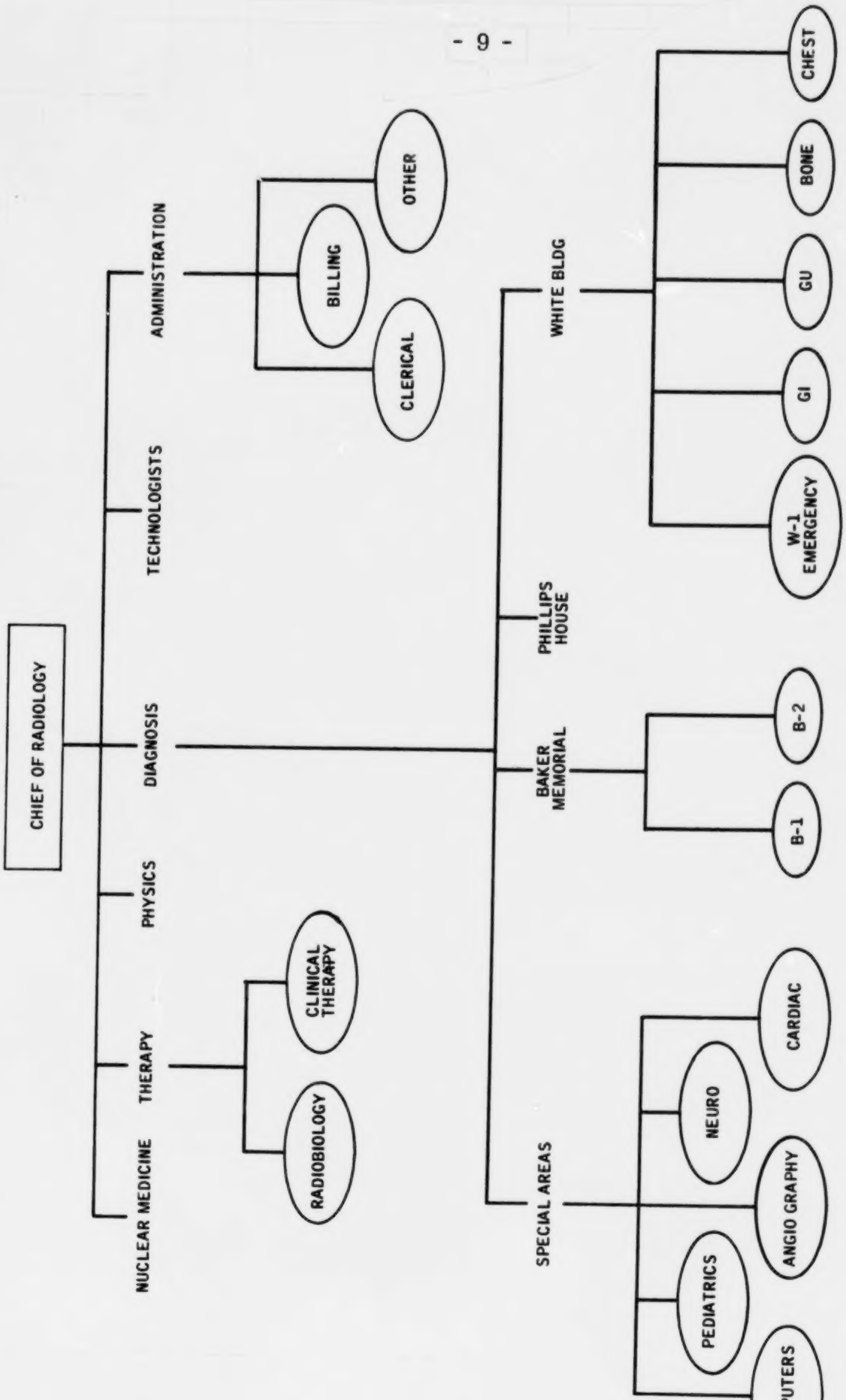
CHIEF OF RADIOLOGY
NUCLEAR MEDICINE
THERAPY
PHYSICS
DIAGNOSIS
TECHNOLOGISTS
ADMINISTRATION
RADIOBIOLOGY
CLINICAL THERAPY
CLERICAL
BILLING
OTHER
SPECIAL AREAS
BAKER MEMORIAL
PHILLIPS HOUSE
WHITE BLDG
COMPUTERS
PEDIATRICS
ANGIO GRAPHY
NEURO
CARDIAC
B-1
B-2
W-1 EMERGENCY
GI
GU
BONE
CHEST

Figure 1. MGH Radiology - Functional Organization

The physical layout of the department is shown in Appendix A, where floor plans are presented of all the areas where radiological functions are performed.

The efficiency of any operation is closely related to certain functional, geographical, and organizational arrangements. In subsequent sections it is suggested that improvements in these areas will lead to increases in efficiency. However, these increases are not solely the product of automated data processing (ADP) and improved communications techniques but also result from careful planning which allows better utilization of existing resources. This planning is predicated on the quantitative description of the department; its activities, its requirements, and its objectives.

The introduction of ADP techniques cannot, of itself, increase department effectiveness. Organization of functions, facilities, personnel, and communications, both intra- and interdepartmentally must proceed if the potential benefits from ADP are to be realized. This report considers the above aspects of organization and their impact on the effectiveness of the department. For example, although an informal chain of command exists within the department at present, a formalized hierarchy which defines lines of authority is lacking. As a result, departmental goals and objectives may not be clearly communicated. There is ample but often divergent staff opinion on ways and means to solve departmental problems, but the lack of effective functional structure prevents maximum use of the problem-solving resources which are available.

Bringing the radiologist and the patient together in a room with appropriate treatment or examination facilities is one of the immediate and day-to-day problems encountered in the Radiology department. As we discuss later, this is one of the problems that can benefit from the application of ADP techniques, provided that the organization of the department allows these potential benefits to be realized.

As an example of the importance of and difficulty in arriving at an effective organization of personnel and resources, we can consider in an introductory manner organizational aspects within the radiology departments. We can assume for the moment that some worthwhile objectives are (a) to make effective use of the radiologist's time, (b) to make better use of the clinician's time when he is in the department, and (c) to advance the quality of patient care and service standards (with consequent improvements in teaching and research functions). If the departmental organization is measured against these objectives, it is seen that the department is geographically divided, and the use of the subdivisions is correlated with the economic status of the patient. This fact alone suggests some reorganization before ADP benefits can be maximized.

Included in the recommendations resulting from this study are suggestions for organizational changes which, in our opinion, would result in a more effective and efficient department, irrespective of the implementation of an ADP system.

2.2.2 Interdepartmental Relationships

The Radiology department is dependent on the rest of the hospital for many goods and services as well as a supply of patients and professional opinions about the patients. The flow chart of Figure 2 reveals the major types of patient, personnel, information, and material flow encountered in the relationship between diagnostic radiology and other areas, both internal and external to it. The reader will note that there are important nonmedical functions associated with radiology, such as professional billing and hospital accounting. These functions are described in greater detail in Section 3. When interdepartmental problems arise, they are largely in the area of communication. To achieve an accurate, timely, and fast communication ability within an organization as complex as the MGH is difficult. Many communication routes are available, each with its own strengths and weaknesses. The use of ADP introduces the potential for another communication pathway.

Computer-based systems are unique in that they most effectively communicate with other machines. The primary concern of this study was to capitalize on this capability. This included a review of present and planned hospital-wide ADP (see Appendix F) and possibilities for interfaces with a radiology ADP system. Our study has also covered ways to make present communication modes more effective with or without a computer/communication terminal system.

One of the serious problems in employing computer terminals lies in achieving the levels of training and acceptance necessary to allow the terminal to realize its full potential as a communication device. Although the selection of the optimal terminal for the Radiology department is beyond the scope of this study, it is possible to recommend one class of terminals over another for some particular purpose.

2.2.3 Department Growth

Patient Growth -- One of the clearly recognizable and serious problems facing most hospital medical departments is the shortage of highly trained medical specialists. The Radiology department at MGH is not exempt from this problem. The need for radiological services is increasing in several significant ways.

An important area of growth is in new diagnostic techniques. Timely examples are nuclear medicine and angiography, which have created entire new fields of subspecialty endeavor within radiology. In addition, many more sophisticated

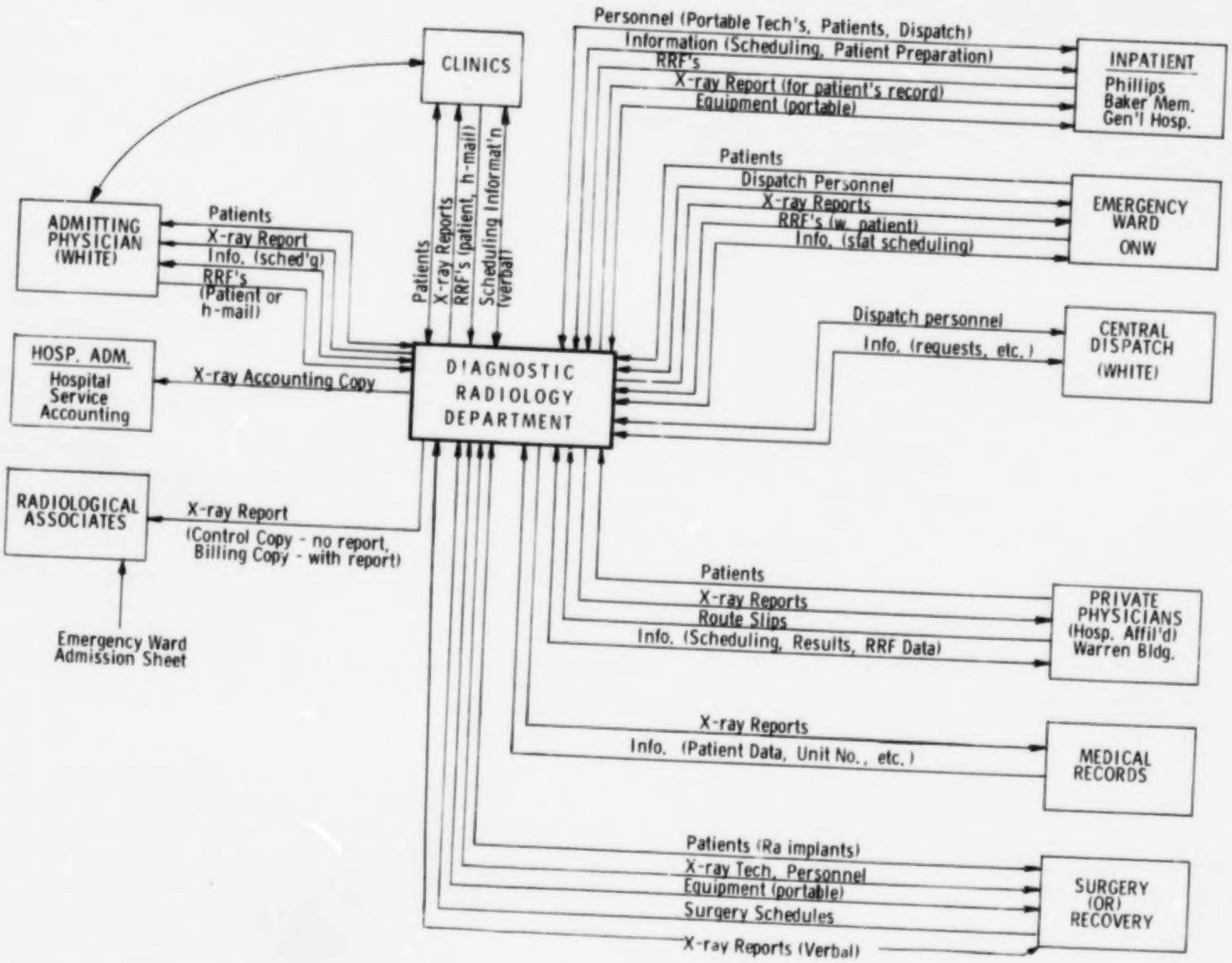
Personnel (Portable Tech's, Patients, Dispatch)
Information (Scheduling, Patient Preparation)
RRF's
X-ray Report (for patient's record)
Equipment (portable)
INPATIENT
Phillips
Baker Mem.
Gen'l Hosp.
CLINICS
Patients
X-ray Reports
RRF's (patient, h-mail)
Scheduling Informat'n (verbal)
ADMITTING PHYSICIAN (WHITE)
Patients
X-ray Report
Info. (sched'g)
RRF's (Patient or h-mail)
Patients
Dispatch Personnel
X-ray Reports
RRF's (w. patient)
Info. (stat scheduling)
EMERGENCY WARD
ONW
HOSP. ADM.
Hospital Service Accounting
X-ray Accounting Copy
DIAGNOSTIC RADIOLOGY DEPARTMENT
Dispatch personnel
Info. (requests, etc.)
CENTRAL DISPATCH (WHITE)
RADIOLOGICAL ASSOCIATES
X-ray Report
(Control Copy - no report, Billing Copy - with report)
Emergency Ward Admission Sheet
Patients
X-ray Reports
Route Slips
Info. (Scheduling, Results, RRF Data)
PRIVATE PHYSICIANS (Hosp. Affil'd) Warren Bldg.
X-ray Reports
Info. (Patient Data, Unit No., etc.)
MEDICAL RECORDS
Patients (Ra implants)
X-ray Tech. Personnel
Equipment (portable)
Surgery Schedules
X-ray Reports (Verbal)
SURGERY (OR) RECOVERY

Figure 2. Diagnostic Radiology Flow Chart - MCH Services

diagnostic and therapeutic procedures have recently been developed within established areas of radiologic practice. These all demand increased floorspace, specialized equipment, and a great deal of the radiologist's time. One important consequence of initiating new special procedures is the increasing proportion of the patient population which can benefit from these radiological services. Other factors also contribute to the expanding number of patients requiring the services of the radiologist. The population in general is increasing, especially the urban (suburban) population served by MGH. Of even greater impact is the increasing usage of prepaid medical insurance programs such as Blue Cross-Blue Shield and the state and federally sponsored health service programs such as Medicare and Medicaid.

Statistics are presented in Appendix D which describe the rate of growth of examination and patient loads within the last several years within MGH Radiology. The rate of increase of examinations performed averages 7-1/2 percent per year, while the number of patients seen has increased at a rate of approximately 7 percent over the last two years.

Facilities Growth -- Just as the ratio of radiologists to examinations given is decreasing, so too is the ratio of floorspace to examinations. MGH statistics indicate that, for the 10-year period ending in 1967, the number of examinations increased by 98 percent while the amount of diagnostic space available was increased only by 51 percent.*

Floorspace utilization has not changed significantly since 1967, although additional space will be made available in the new Gray Building by 1970. This action will improve the ratio of floorspace growth rate to examination growth rate, but it will certainly not make the two comparable. The important implication of these facts is that increased efficiencies in radiologist time and floorspace utilization must be found, at least until adequate floorspace and professional staff become available. It is difficult to conceive of a time when such adequacies can be achieved.

2.2.4 General Goals and Requirements

Generally it is thought that people have the ability to set meaningful goals or objectives, believing that they move in a reasonably straightforward fashion in achieving these goals. In reality, however, we typically recognize some difficult sets of circumstances and then analyze the various factors contributing to these circumstances and make some sort of futuristic statements which are loosely definable as goals. In other words, the circumstances set the goals under our supervision.

---

*"A Report on Diagnostic Radiology to the General Director of the MGH," Department of Radiology Staff Planning Committee, February 27, 1967.

In this study, Honeywell essentially plays the role of supervisory assistant. We have attempted, by working with the radiology staff, to aid in arranging circumstances into goals.

The following broad goals have been defined:

- To provide the best possible patient care
- To improve the methods used in training physicians and students to be radiologists and radiological technologists, respectively
- To perform significant research on new techniques and their application to radiology

Each of these goals carries with it a wide variety of implications which may differ, and possibly conflict, when viewed through the eyes of the people most centrally involved in the radiologic process: the patient, clinician, radiologist, and technologist. From the patient's viewpoint, "best possible care" implies a rapid and accurate diagnosis of his particular illness. It implies a minimizing of inconvenience and of time consumed in carrying out the diagnostic procedures, and also a certain degree of shielding and privacy from other patients and hospital personnel during the waiting times associated with the examination. The patient's needs must be considered and will vary depending upon the nature of the patient (i.e., ambulatory, bedridden, young, old, etc.). Facility and patient care requirements will be different for each and some care should be paid to these differences.

From the radiologist's viewpoint, "best patient care" carries a different meaning. His primary objective in the pursuit of excellence in patient care is to provide an accurate diagnosis and report concerning the patient's condition to the clinician as rapidly as possible and in such a way as to avoid any misunderstandings concerning the diagnosis.

To achieve this goal, the radiologist must be concerned with the availability of adequate facilities, including equipment, space and technical assistance, for performing and interpreting roentgen examinations. It means that he have rapid access to all patient information necessary to make an accurate diagnosis, information in the form of past X-ray films and reports, as well as present clinical data on the patient. It emphasizes the necessity of translating his diagnostic impressions rapidly into a form which is useful to the patient's attending physician. While pursuing this primary goal, the radiologist also strives to provide the utmost in patient comfort and convenience during the X-ray process, satisfying to the best of his ability the patient needs cited above.

The technologist also plays a crucial role in achieving excellence in patient care. He is responsible for working with the patient in the examination room, loading and using the X-ray machine properly, checking the films for quality and adequacy, and preparing the examination room for subsequent patients. To accomplish these tasks in an optimum manner he must have adequate room and facilities for patient preparation. He must have the use of modern X-ray equipment, adequate for the variety of radiographic procedures he is to perform. This equipment must be constantly checked and maintained in order to avoid machine downtime and the resulting bottlenecks. He must also have an extreme degree of familiarity with the type of equipment he is using and the type of patient involved in order to minimize film retakes and the consequent exposure of the patient to unnecessary X-radiation.

In carrying out its teaching function, the department staff interacts with both student technologists and residents. The training programs are both formal and informal in nature. The informal portion is accomplished simply through the assistance of staff radiologists and technologists to student personnel in the performance of their day-to-day duties. Formal training is achieved through organized meetings and teaching sessions occurring on a frequent basis. An example is the series of daily conferences for the staff and residents where interesting diagnostic cases are presented and discussed. In these teaching situations, a number of needs arise. Conference facilities must be available in the form of adequate-sized rooms, seating space, viewing facilities, etc. Student and staff schedules must be arranged in such a manner that time will be available during and after the working day for teaching conferences. Finally, resource material must be readily available to the staff to serve as subject matter. This may take the form of special series of X-ray films demonstrating the pathological progression of diseases of interest; unusual manifestations of certain disease forms, etc. Ready accessibility to patient histories and past films is therefore required. In part this need is satisfied through the maintenance of a special teaching collection of X-ray films within MGH Radiology. In many instances, however, ready access to additional patient films is both necessary and desirable, yet difficult to achieve because of the outmoded characteristics of the film filing system presently in use within MGH and other radiology departments of large teaching hospitals.

The third goal of the department is to perform significant research in the field of diagnostic radiology. This goal is subservient to the first two and, as such, is perhaps the most difficult to achieve. With presently existing workloads within the department at MGH, the radiologist is already overburdened simply with the performance of his "normal" duties in the areas of patient care and teaching functions. Research in other areas of interest is in many cases the result of dedication and personal sacrifice on the radiologist's part and not because of any scheduled research activities. The needs in this area are therefore evident -- not only adequate facilities and an increase in trained radiologists (commensurate with the rate of growth of the patient population) but a streamlining of the radiological system, of which the radiologist is so crucial a part, are required.

2.2.5 Recent Changes and Improvements

In keeping with the desire to provide excellence in patient care, a number of changes for the improvement of operational efficiency have been made within MGH Radiology over the past several years. These changes were in part necessitated by the continually increasing number of radiological procedures requested (at an approximate rate of 7-1/2 percent per year). As an example, whereas formerly most X-ray examinations were not scheduled, now almost all are to varying degrees. Moreover, there is increased interdepartmental utilization of X-ray rooms, and in the White-2 service there has been a move towards subspecialization with the assignment of radiologists to interpreting examinations in a particular subspecialty area (e.g., gastrointestinal, genitourinary, bone, chest). These changes have resulted in more efficient utilization of X-ray machines as well as the more even distribution of workloads. Furthermore, private ambulatory patients have been moved to the first floor of Baker to allow all private inpatients (Baker and Phillips) to be on the same floor level, alleviating certain patient logistics problems. Also, film processing has been fully automated, better film-loan control has been established for White-1 radiology, and film retrieval has been simplified on White-2 by use of color codes and terminal digit filing.

Another development is the forthcoming increase in space with the move to a new but nearby wing of what is known as the Gray Building. This will allow room for the great expansion in special procedures type examinations. It will also provide space for a consolidated White file system, an "active file" area, as well as work areas for film sorting and loan-out activities and for interpretation and consulting rooms for White in- and outpatients' films. The pending move will allow for expansion of the teaching collection file, study room, and patient waiting areas into the former White-2 file rooms and conference rooms.

Even though these actions by MGH personnel have done much for improving the efficiency of operations, problems still do remain. The need for continued improvement in regard to patient handling is reflected in the extended pre- and post-examination patient waiting times which may be attributed to inefficiency encountered in information flow between nursing stations, technologists and/or schedulers.* The need for greater efficiency is also revealed in the difficulties found in gaining reliable access to certain old films and reports, and in time delays encountered between the time a film is read and the time the translation of the impression reaches the physician or patient's medical record. The members of the study team feel, however, that these needs can be satisfied in

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*Improved scheduling procedures, instituted at the approximate time of the data-gathering task, have since resulted in shorter pre- and post-examination waiting times. It was not possible to gather and incorporate data reflecting these changes under the scope of the present study.

large measure through: (1) the use of advanced communication and information storage concepts within MGH Radiology and (2) concurrent changes in the organizational structure of the Radiology department. These recommendations are discussed in more detail in the remaining sections of the report.

SECTION 3
DIAGNOSTIC RADIOLOGY AT MGH

This section describes the process of moving a patient through the radiological system and discusses the associated administrative processes. It seems appropriate, however, to first describe in brief the service provided by the five radiology subareas. Statistics on the examination types, patient loads, etc., for the areas are presented in text and described in more detail in Appendix D.

3.1 SUBAREA FUNCTIONS

3.1.1 Phillips House

Phillips House serves private inpatients of more than moderate means, at a current rate of about 6,700 per year. There is one staff radiologist and two X-ray technologists in attendance. Of the two examination rooms available, one has facilities for conducting chest examinations, fluoroscopies, and general radiographic procedures, while in the other only general procedures are done.

3.1.2 Baker Memorial

Baker-1 is for private-ambulatory or outpatients and serves about 14,000 patients annually. One staff radiologist is assigned each day from the Baker Radiology staff to conduct fluoroscopies and special examinations, and to supervise the five X-ray technologists. Of the four radiographic machines, two are for general radiographic studies and two are for fluoroscopies as well as general radiographic studies.

Baker-2 takes care of private inpatients and all pediatrics cases at a current level of about 25,000 per annum. There are six staff radiologists, two residents, and eight floor X-ray technlogists (plus one assistant chief technologist and three "portable" technologists). Chest examinations may be done in any one of the five examination rooms. All-purpose examinations are taken care of on either of three machines, and fluoroscopies and any special procedures such as arthrograms or bronchograms, as well as general radiographic studies, are performed on the remaining two machines.

3.1.3 White Building

White X-ray is physically divided into White-1, which services the Emergency Ward and the Overnight Ward, and White 2, which is primarily for clinic and in-patients on the teaching services.

White-1 processed 36,400 patients in 1967-68 and is staffed by one to two staff radiologists, two to three residents, and eight to ten technologists within any 24-hour period. Many of these individuals rotate from a larger personnel pool on W2. There are four examination rooms, two for general radiographic procedures, and two in which fluoroscopies are done in addition to general examinations.

There were 43,000 examinations performed on W2 in 1967-68. This department is organized according to subspecialty areas of radiology such as gastrointestinal (GI), genitourinary (GU), bone, and chest, and has a total of 16 technologists plus 7 radiologists and 10 residents. Each subsection has its own complement of rooms (two each for chest, bone, and GU and three for GI) as well as its own technologists and radiologists. Some of the special-procedure sections such as nuclear medicine and neuroradiology also occupy rooms on W2, but these groups are soon to be transferred to larger facilities in a newly completed wing of the hospital.

3.2 RADIOGRAPHIC PROCEDURES

The first part of the following discussion describes the pre-X-ray examination procedures presently followed within the five radiology subdepartments. The superscripts refer to patient source areas, as listed, where procedures differ to some degree. Detailed process sequence narratives for the overall patient-radiological process are presented in Appendix B for each of the five diagnostic radiology areas within MGH.

Superscript	Patient Source Area
1	Emergency Ward (EW)
2	Overnight Ward (ONW)
3	White inpatients (W2)
4	Clinic patients (W1)
5	Baker inpatients (B2)
6	Phillips House (PH)
7	Baker ambulatory (B1)

3.2.1 Bringing the Patient and X-ray Machine Together

The act of bringing the patient and X-ray machine together is primarily a scheduling function. Table 3 is a summarization of this process; the detailed procedure is described in the following paragraphs.

Prior to the patient's arrival in one of the five radiology areas within MGH, a physician has examined the patient initially to determine if an X-ray is warranted. If it is, the physician then completes the radiological request form (RRF) himself[1-6] or he may have one of the floor personnel fill one out (either from notations in the order book or scratch pad made during rounds or by verbal communication), after which he affixes his authorizing signature.[3,4,6] (The doctor's written consent is not needed for standard

Table 3. Summarized Process Sequence Pathway -- Scheduling

Sequence	Procedure
1-2	Physician examines patient and decides X-ray is necessary
2-3	Authorization for examination is recorded at nursing station and via RRF
3-4	Decision is transmitted to scheduler from floor
	a) verbally with appointed time given and recorded at nursing station and scheduling desk
	b) and/or via RRF -- with received RRF's sorted and examination schedules made up
4-5	At the time of impending examination, scheduler notifies floor dispatcher
5-6	Dispatcher retrieves patient from floor
6-7	Technologist obtains RRF and corresponding patient
7-8	Patient is transported to room and examination is conducted

pre-operative chest RRF's made out for pre-admission patients by the unit coordinator or for routine pre-employment chest films originating from the MGH Staff Clinic.) The examination appointment time may be arranged by the unit coordinator [3,5,6] with the appropriate area receptionist for patients requiring special preparation (e.g., fasting), or an examination may be booked directly by the physician [1,2,3,7] with the receptionist. The patient's examination notice is recorded on the floor in the (a) nurses' SCUT (work) sheet and (b) Travel Book [3,5,6]. The unit coordinator then sees to it that the collected RRF's are dropped off in the RRF pickup box by about 8:00 am on the day of the examination (for chest and bone X-rays) or by 4:00 pm of the day preceding the examination [for fluoroscopies, IVP's, GB's or special procedures (W2 and B2 Radiology departments)]. In Phillips House, for those patients not requiring preparation (e.g., chest and bones), the unit coordinator sends the RRF to PH radiology without advance notice or holds it so it may accompany the patient at the assigned time.

Concerning the W1 procedures, the patients coming through W1 radiology may be Emergency Ward (EW) patients, section X-ray requests, or overnight ward admissions (ONW). When a patient arrives, the time of arrival, patient log number, and other pertinent information are recorded. The RRF's accompanying the patient are arranged sequentially and the admission sheets are stacked to be sent to the Radiological Associates file. Moreover as (a) RRF's are received from ONW, they are subdivided by examination type and scheduled accordingly for the day, and (b) as floor requests for X-ray examinations are phoned in, the White-1 Radiology medical secretary compiles an inpatient list, and as soon as an opening occurs, the floor is notified.

For the purpose of scheduling examinations, the White-2 radiology reception-scheduling desk receives RRF's from the following sources: (a) from White-1 radiology (between-shifts personnel), (b) from the RRF "pickup box," (c) from floor and clinic personnel, and (d) from clinic patients having examinations done the same day they were seen by the admitting physician. For both White-2 and Baker-2, the RRF's are sorted according to examination type and the date the examination is requested. The general pattern kept in mind by schedulers while setting up the examination schedule for the day is to require the relatively more complex examination procedures (necessitating the attendance of a radiologist -- as laminograms and other special procedures, fluoroscopies, GB's,IVP's) be assigned specific times and take temporal priority over less involved examinations such as chests and bones. The latter routine examinations are allowed more leeway in terms of scheduled time. On W2, for example, there are certain times set aside when no specific number of patients are scheduled, and they are merely logged as they arrive with their RRF (as in the four-hour block set aside for the Fracture Clinic).

In setting up an appointment on Baker-1, the medical secretary may receive a call from the physician or his secretary to arrange for a patient examination time. She also receives a "Baker-1 yellow route slip" by mail or from the patient and, referring to it and/or Central Filing for additional patient data, fills out the RRF. Furthermore, Baker-1 arranges all mammographies (done in Phillips House radiology) and also takes care of scheduling laminographies for Baker-2 and Phillips House.

In Phillips House, the technician is the one who schedules examinations from RRF's received according to the following sequence of immediacy: (a) pre-operative chest X-rays; (b) fasting cases (fluoroscopies, IVP, GB); (c) radium implants and films for scans. Bones and non-fasting cases are not booked and are taken when space is available.

In transporting the patient back and forth from the radiology department White-1, White-2 and Baker-2 normally use a dispatch service. On White-1 the medical secretary indicates to the dispatcher either the patient's appointed time or the fact that the technologist is now ready to do an examination and then notifies the ward (Overnight Ward or Emergency Ward) that the dispatcher is on his way. In contrast, on Baker-2 and White-2, the receptionist refers to the RRF file and time slot assigned to a patient, calls the floor to give advance notice to nursing personnel for getting the patient ready, and gives the corresponding "dispatch service route slip" to the dispatcher who retrieves the patient. After the examination is completed, patients from White-1 radiology are returned to the Emergency Ward or Overnight Ward before being transported to their eventual destination. From White-2 and Baker-2 radiology, the patients are returned to their respective floor or boarding areas with the aid of a return "route slip." In contrast, clinics must provide their own dispatch services; however, Baker-1 may call on the Main Dispatch Office if an occasional outpatient needs transportation back to the physician's hospital office. In Phillips House, the task of transporting patients between the White-1 or Phillips House radiology areas is assigned to nurses or hospital dispatch personnel who are in contact with the X-ray technologist.

3.2.2 The Radiologic Examination and Retaining the X-ray or Fluoroscopic Image

To conduct the X-ray examination, the technologist on White-1, White-2 or Baker-2 first takes the appropriate RRF from the receptionist and then gets the corresponding patient. On Baker-1 the technologist is contacted by the medical secretary to pick up the patient together with the X-ray control copy of the RRF. The examination is conducted, and the exposed films are given to the dark room technician for development, after which he initials the RRF and enters the number and size of films therein.

Most of the films are quality checked by the respective X-ray technologists; however, for more involved cases (fluoroscopies, GB's, IVP's, etc.), the radiologist will most likely be consulted. The patient usually waits while the films are being checked, except for house patients on White-2 who are normally sent back to the floor without awaiting a decision on whether a retake is needed. (For a retake, the RRF is sent back to the receptionist and the patient is recalled from the floor.) The technologist has authority to dismiss the patient in most cases, except on W1 where explicit approval of the radiologist is needed. After the films have been judged acceptable in White-1 radiology, the next steps are: the technologist (a) for ONW patients fills in a "yellow X-ray check list" to accompany the patient back to the ward, (b) makes up a loan folder to contain the new films and RRF, and (c) files this in the radiologist's cart. On White-2 radiology, the quality control technologist (a) puts newly taken films and corresponding RRF's into a new-film envelope, (b) files this in the "Quality Control Room - File Room" partition file, and (c) for clinic patients calls the receptionist to indicate the patient may be released. On (a) Baker-2 and Phillips House, the approved new films with the RRF and on (b) Baker-1 the X-ray control copy, "yellow route slip", and new-film packet are taken to the respective file room areas by the X-ray technologist.

3.2.3 Recording and Transmission of the Diagnosis

In giving a current diagnosis, the radiologist usually has at hand a packet of pertinent old films and reports as well as the new films and the attending physician's clinical comments contained in the RRF. In White-2 radiology, a radiologist is assigned reading of films of one of four particular subspecialty types -- bones, chest, GI or GU -- while, in the other areas, there is no such division of activity. After the films have been viewed and the interpretation dictated, the medical secretary pulls the corresponding dictation tapes and transcribes the diagnostic information onto the RRF. Then she obtains the radiologist's approval (signature) on the typed report and distributes the copies of the RRF as follows:

(1) The X-ray control copy and orange copy go to Radiological Associates.

(2) The X-ray file copy is put inside the manila folder inside the master film envelope (all radiology subsections); the new and old reports are then brought to file room.

(3) The physician's copy is mailed to the attending physician, (B1, B2, W2, PH) or placed in the patient's chart until the medical records copy is received and signed by a staff radiologist (W1).

(4) The medical records copy is sent to the floor to be inserted in the patient's chart and then upon his discharge to Central Medical Records (B2, W1, PH). B1 sends the Medical Records copy directly to Central Records and, for new patients, includes the first two short copies of the Baker-1 RRF.

In stat cases, a "wet reading" may be given over the phone to the floor or operating room (or the physician, as is the case for Baker-1 ambulatory patients) after which a medical secretary enters this into the patient's chart. In addition, stat readings may be (a) given via teleautograph as used in W1 emergency X-ray, (b) handwritten on a special "pink slip" which is sent to the attending physician or operating room as in B2, or (c) printed directly on the RRF by the radiologist and handed to the medical secretary. A summary of the reporting process is presented in Table 4.

Table 4. Summarized Process Sequence Pathway -- Reporting

Sequence	Procedure
1-2	Radiologist retrieves collated films and reports from "unread" section in viewing room.
2-3	Radiologist gives interpretation into dictaphone, referring to old films and reports.
3-4	Radiologist puts these in a temporary "read" file.
4-5	Medical secretary picks up tapes and corresponding RRF's and transcribes the report onto the RRF.
5-6	Report is returned to radiologist for correction and signature.
6-7	Copies of RRF are dispensed in routine manner by the medical secretary.

3.2.4 Storage and Retrieval of Obtained Information

The radiologist usually has access to all pertinent old films and reports for reference in making his diagnosis. The file clerk is in most cases the one who originally retrieves these and is aided by one of the following pieces of information:

(a) the file room copy of the RRF or data therefrom, copied onto a daily worksheet (W2, B2, PH)

(b) the RRF (minus the X-ray control copy) or worksheet (B1)

(c) a phone call from the radiologist or medical secretary (W1)

Next the file clerk refers to the Patient Index to see if old films exist and where, and she retrieves them from the file room going by terminal digits of the patient's unit number as the filing system is organized there (pediatric films on Baker-2 are filed by the first three digits). Appendix C describes the color-coding schemes used to augment the terminal digit filing system which is based on the patient's history number. After the master envelopes (MEV) are found, old films and reports which are of the same subspecialty examination types as the current X-ray are selected out. These are placed outside the MEV and collated with the new films and reports which are received from the technician (B1, B2, PH) or through the Quality Control-File Room slot file (W2). This collated subpacket is either (a) placed in a clear plastic envelope (W2) together with the master envelope, (b) put in a "loan out" folder (PH) (with the master envelope not leaving file room) or (c) inserted under the flap of the master envelope (B1, B2). They are then transported to the "unread" file of the corresponding radiologist's viewing area; on White-2 the file clerk mounts films on the alternators corresponding to the subspecialty examination.

For White-1 radiology film requests, the respective file clerk may bring requested old films to the radiologists' cart file there or have a White-1 messenger pick them up.

After the films have been interpreted, the master folder is either (a) transferred immediately back to the file area (PH), (b) first filed for 24 hours in a "read" section of the viewing area (B1, B2), (c) filed in a temporary viewing room file until the end of the shift (W2) or (d) filed in a temporary cart until the respective file clerks retrieve the master folders for patients assigned to their hospital area (W1) and take them back for final reading and signature. The subspecialty examinations are put back inside the respective master envelopes, the master envelope is color-coded appropriately by tape (W2) and then refiled in the regular room file (except for White in- and outpatients which are first filed for six weeks in the "Active File" on White 2). A summary of the film handling process in presented in Table 5.

Tables 3 through 5 present the major steps performed in the patient scheduling, film handling, and X-ray reporting processes. Describing these steps as they apply in each of the radiological services results in a complicated narrative. Therefore, block flow diagrams which illustrate the processes are presented in Figures 3 through 10 with the hope they will further clarify this complicated sequence of events.

Table 5. Summarized Process Sequence Pathway -- Film Handling

Sequence	Procedure
1-2	File clerk gets old film retrieval information.
2-3	File clerk checks Patient Index for presence and location of old record.
3-4	File clerk retrieves old film packet by unit number.
4-5	File clerk places film folders in "holding file".
5-6	X-ray technologist delivers exposed film and RRF to dark room technician.
6-7	New films are processed and quality checked.
7-8	File clerk gets new films and RRF's and collates with the appropriate old records and films.
8-9	Entire packet is transferred to viewing room "unread" file.
9-10	After diagnosis is given folders are filed in viewing room "read" file.
10-11	File clerk transports film packets back to main room and color codes and refiles them.

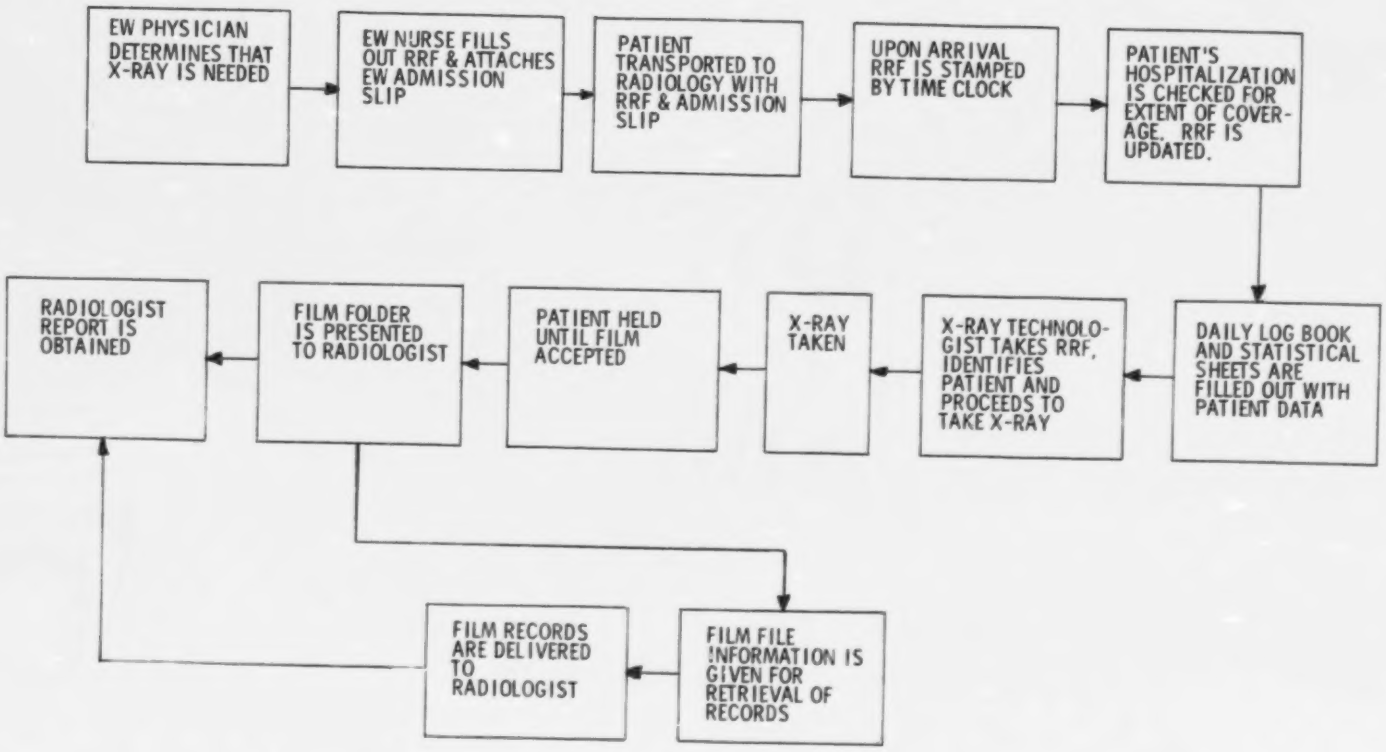

EW PHYSICIAN DETERMINES THAT X-RAY IS NEEDED
EW NURSE FILLS OUT RRF & ATTACHES EW ADMISSION SLIP
PATIENT TRANSPORTED TO RADIOLOGY WITH RRF & ADMISSION SLIP
UPON ARRIVAL RRF IS STAMPED BY TIME CLOCK
PATIENT'S HOSPITALIZATION IS CHECKED FOR EXTENT OF COVERAGE. RRF IS UPDATED.
DAILY LOG BOOK AND STATISTICAL SHEETS ARE FILLED OUT WITH PATIENT DATA
X-RAY TECHNOLOGIST TAKES RRF, IDENTIFIES PATIENT AND PROCEEDS TO TAKE X-RAY
X-RAY TAKEN
PATIENT HELD UNTIL FILM ACCEPTED
FILM FOLDER IS PRESENTED TO RADIOLOGIST
RADIOLOGIST REPORT IS OBTAINED
FILM FILE INFORMATION IS GIVEN FOR RETRIEVAL OF RECORDS
FILM RECORDS ARE DELIVERED TO RADIOLOGIST

Figure 3. White-1 (Emergency Ward) Patient Examination Sequence

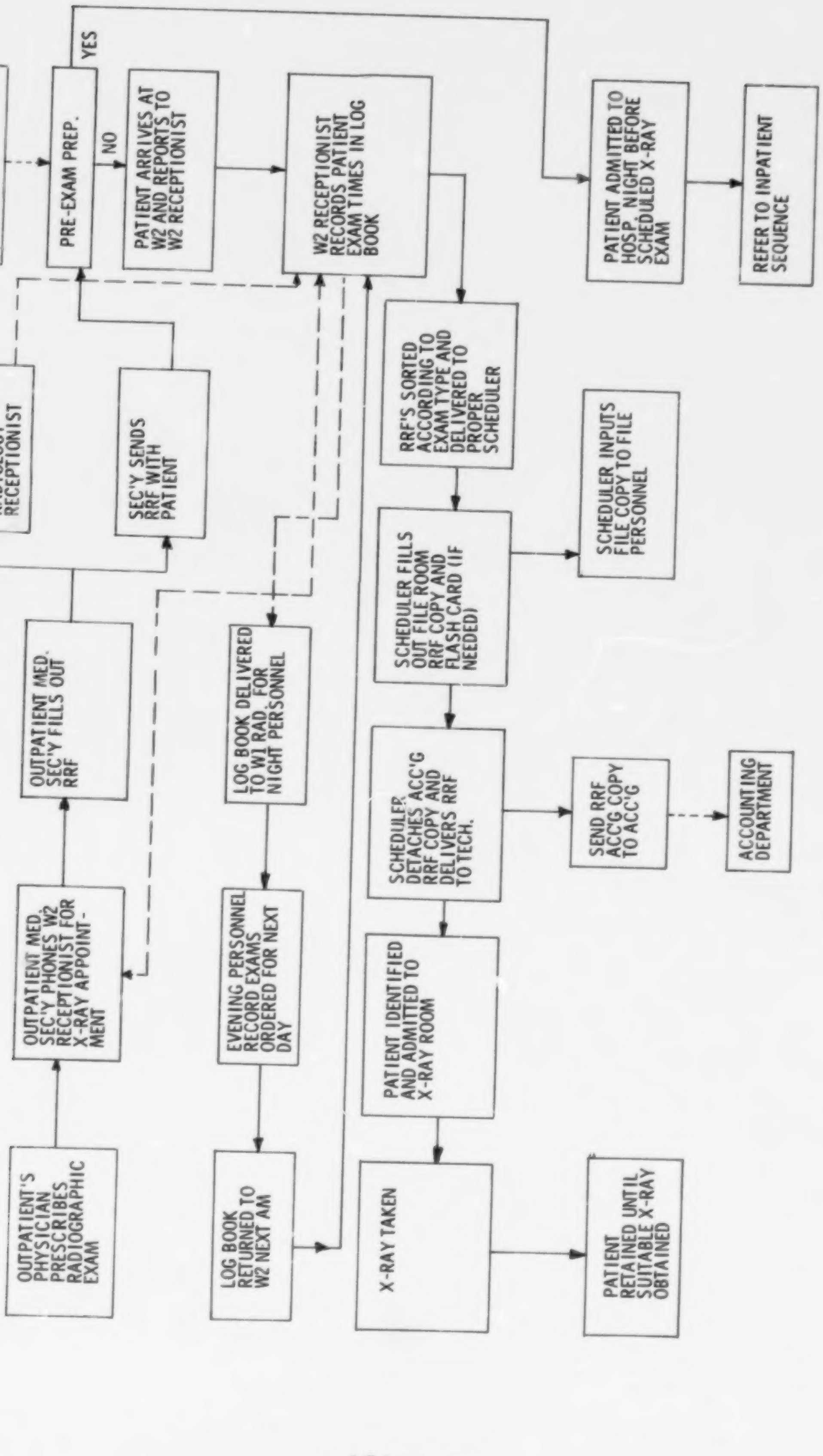
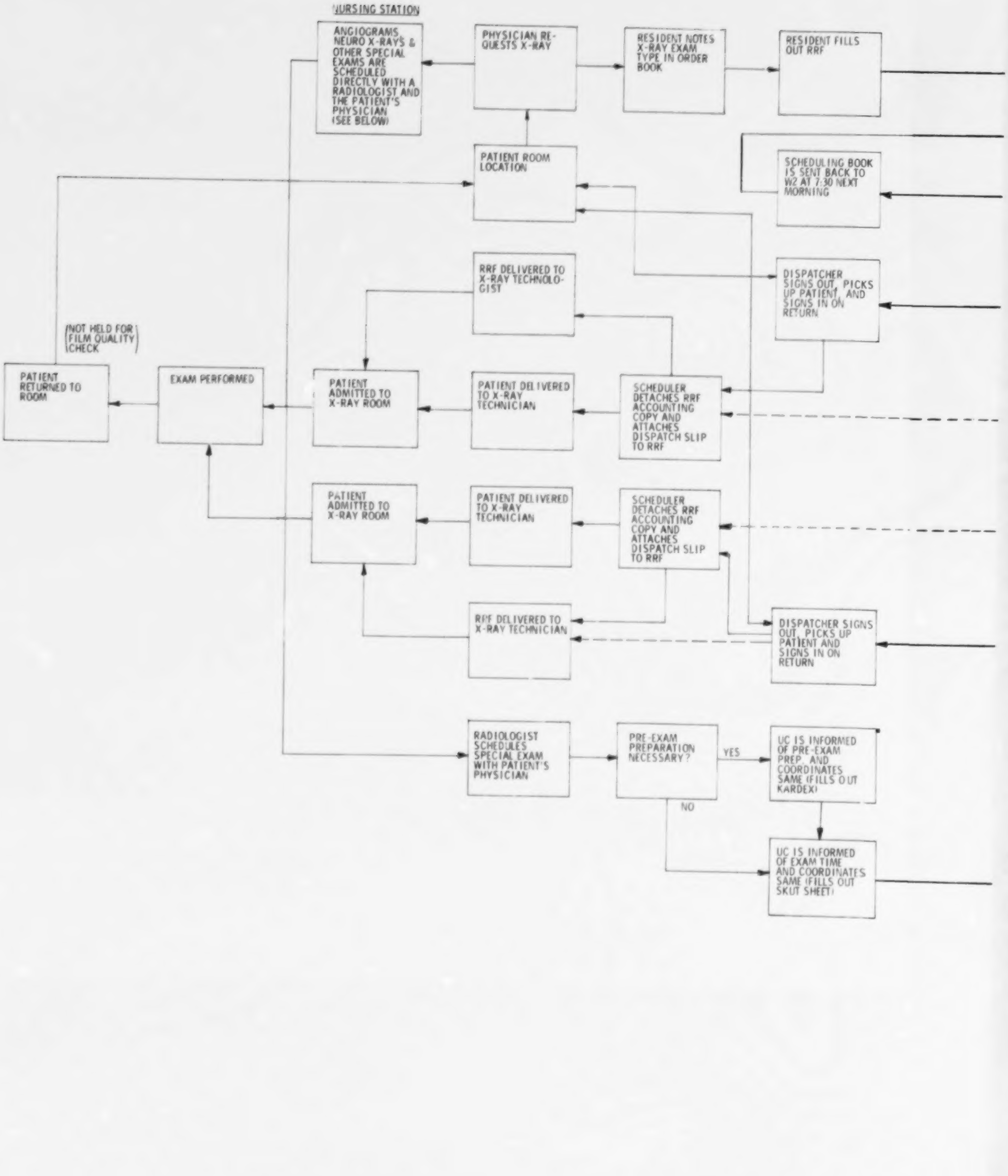

OUTPATIENT'S PHYSICIAN PRESCRIBES RADIOGRAPHIC EXAM
OUTPATIENT MED. SEC'Y PHONES W2 RECEPTIONIST FOR X-RAY APPOINTMENT
OUTPATIENT MED. SEC'Y FILLS OUT RRF
SEC'Y MAILS RRF TO W2 RADIOLOGY RECEPTIONIST
SEC'Y SENDS RRF WITH PATIENT
PATIENT SENT HOME
PRE-EXAM PREP.
YES
NO
PATIENT ARRIVES AT W2 AND REPORTS TO W2 RECEPTIONIST
W2 RECEPTIONIST RECORDS PATIENT EXAM TIMES IN LOG BOOK
PATIENT ADMITTED TO HOSP. NIGHT BEFORE SCHEDULED X-RAY EXAM
REFER TO INPATIENT SEQUENCE
LOG BOOK RETURNED TO W2 NEXT AM
EVENING PERSONNEL RECORD EXAMS ORDERED FOR NEXT DAY
LOG BOOK DELIVERED TO W1 RAD. FOR NIGHT PERSONNEL
RRF'S SORTED ACCORDING TO EXAM TYPE AND DELIVERED TO PROPER SCHEDULER
SCHEDULER FILLS OUT FILE ROOM RRF COPY AND FLASH CARD (IF NEEDED)
SCHEDULER INPUTS FILE COPY TO FILE PERSONNEL
SCHEDULER DETACHES ACC'G RRF COPY AND DELIVERS RRF TO TECH.
SEND RRF ACC'G COPY TO ACC'G
ACCOUNTING DEPARTMENT
PATIENT IDENTIFIED AND ADMITTED TO X-RAY ROOM
X-RAY TAKEN
PATIENT RETAINED UNTIL SUITABLE X-RAY OBTAINED

Figure 4. White-2 Outpatient Examination Sequence


NURSING STATION
ANGIOGRAMS NEURO X-RAYS & OTHER SPECIAL EXAMS ARE SCHEDULED DIRECTLY WITH A RADIOLOGIST AND THE PATIENT'S PHYSICIAN (SEE BELOW)
PHYSICIAN REQUESTS X-RAY
RESIDENT NOTES X-RAY EXAM TYPE IN ORDER BOOK
RESIDENT FILLS OUT RRF
PATIENT ROOM LOCATION
SCHEDULING BOOK IS SENT BACK TO W2 AT 7:30 NEXT MORNING
RRF DELIVERED TO X-RAY TECHNOLOGIST
DISPATCHER SIGNS OUT, PICKS UP PATIENT, AND SIGNS IN ON RETURN
(NOT HELD FOR FILM QUALITY CHECK)
PATIENT RETURNED TO ROOM
EXAM PERFORMED
PATIENT ADMITTED TO X-RAY ROOM
PATIENT DELIVERED TO X-RAY TECHNICIAN
SCHEDULER DETACHES RRF ACCOUNTING COPY AND ATTACHES DISPATCH SLIP TO RRF
PATIENT ADMITTED TO X-RAY ROOM
PATIENT DELIVERED TO X-RAY TECHNICIAN
SCHEDULER DETACHES RRF ACCOUNTING COPY AND ATTACHES DISPATCH SLIP TO RRF
RRF DELIVERED TO X-RAY TECHNICIAN
DISPATCHER SIGNS OUT, PICKS UP PATIENT AND SIGNS IN ON RETURN
RADIOLOGIST SCHEDULES SPECIAL EXAM WITH PATIENT'S PHYSICIAN
PRE-EXAM PREPARATION NECESSARY?
YES
NO
UC IS INFORMED OF PRE-EXAM PREP. AND COORDINATES SAME (FILLS OUT KARDEX)
UC IS INFORMED OF EXAM TIME AND COORDINATES SAME (FILLS OUT SKUT SHEET)

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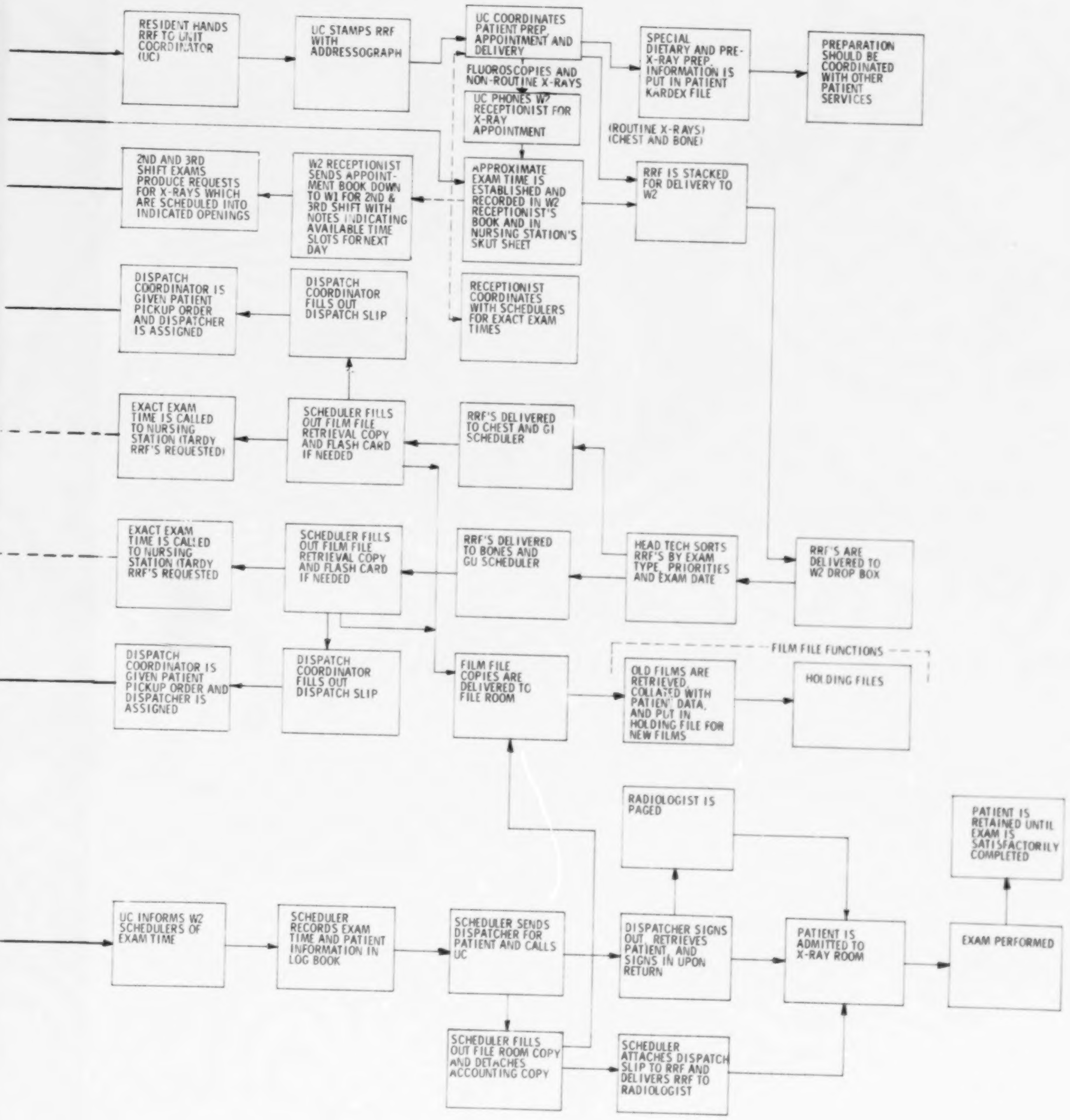

RESIDENT HANDS RRF TO UNIT COORDINATOR (UC)
UC STAMPS RRF WITH ADDRESSOGRAPH
UC COORDINATES PATIENT PREP, APPOINTMENT AND DELIVERY
SPECIAL DIETARY AND PRE-X-RAY PREP. INFORMATION IS PUT IN PATIENT KARDEX FILE
PREPARATION SHOULD BE COORDINATED WITH OTHER PATIENT SERVICES
FLUOROSCOPIES AND NON-ROUTINE X-RAYS
UC PHONES W2 RECEPTIONIST FOR X-RAY APPOINTMENT
(ROUTINE X-RAYS) (CHEST AND BONE)
2ND AND 3RD SHIFT EXAMS PRODUCE REQUESTS FOR X-RAYS WHICH ARE SCHEDULED INTO INDICATED OPENINGS
W2 RECEPTIONIST SENDS APPOINTMENT BOOK DOWN TO W1 FOR 2ND & 3RD SHIFT WITH NOTES INDICATING AVAILABLE TIME SLOTS FOR NEXT DAY
APPROXIMATE EXAM TIME IS ESTABLISHED AND RECORDED IN W2 RECEPTIONIST'S BOOK AND IN NURSING STATION'S SKUT SHEET
RRF IS STACKED FOR DELIVERY TO W2
DISPATCH COORDINATOR IS GIVEN PATIENT PICKUP ORDER AND DISPATCHER IS ASSIGNED
DISPATCH COORDINATOR FILLS OUT DISPATCH SLIP
RECEPTIONIST COORDINATES WITH SCHEDULERS FOR EXACT EXAM TIMES
EXACT EXAM TIME IS CALLED TO NURSING STATION (TARDY RRF'S REQUESTED)
SCHEDULER FILLS OUT FILM FILE RETRIEVAL COPY AND FLASH CARD IF NEEDED
RRF'S DELIVERED TO CHEST AND GI SCHEDULER
EXACT EXAM TIME IS CALLED TO NURSING STATION (TARDY RRF'S REQUESTED
SCHEDULER FILLS OUT FILM FILE RETRIEVAL COPY AND FLASH CARD IF NEEDED
RRF'S DELIVERED TO BONES AND GU SCHEDULER
HEAD TECH SORTS RRF'S BY EXAM TYPE, PRIORITIES AND EXAM DATE
RRF'S ARE DELIVERED TO W2 DROP BOX
DISPATCH COORDINATOR IS GIVEN PATIENT PICKUP ORDER AND DISPATCHER IS ASSIGNED
DISPATCH COORDINATOR FILLS OUT DISPATCH SLIP
FILM FILE COPIES ARE DELIVERED TO FILE ROOM
FILM FILE FUNCTIONS
OLD FILMS ARE RETRIEVED, COLLATED WITH PATIENT DATA, AND PUT IN HOLDING FILE FOR NEW FILMS
HOLDING FILES
RADIOLOGIST IS PAGED
PATIENT IS RETAINED UNTIL EXAM IS SATISFACTORILY COMPLETED
UC INFORMS W2 SCHEDULERS OF EXAM TIME
SCHEDULER RECORDS EXAM TIME AND PATIENT INFORMATION IN LOG BOOK
SCHEDULER SENDS DISPATCHER FOR PATIENT AND CALLS UC
DISPATCHER SIGNS OUT, RETRIEVES PATIENT, AND SIGNS IN UPON RETURN
PATIENT IS ADMITTED TO X-RAY ROOM
EXAM PERFORMED
SCHEDULER FILLS OUT FILE ROOM COPY AND DETACHES ACCOUNTING COPY
SCHEDULER ATTACHES DISPATCH SLIP TO RRF AND DELIVERS RRF TO RADIOLOGIST

Figure 5. White-2 Inpatient Examination Sequence

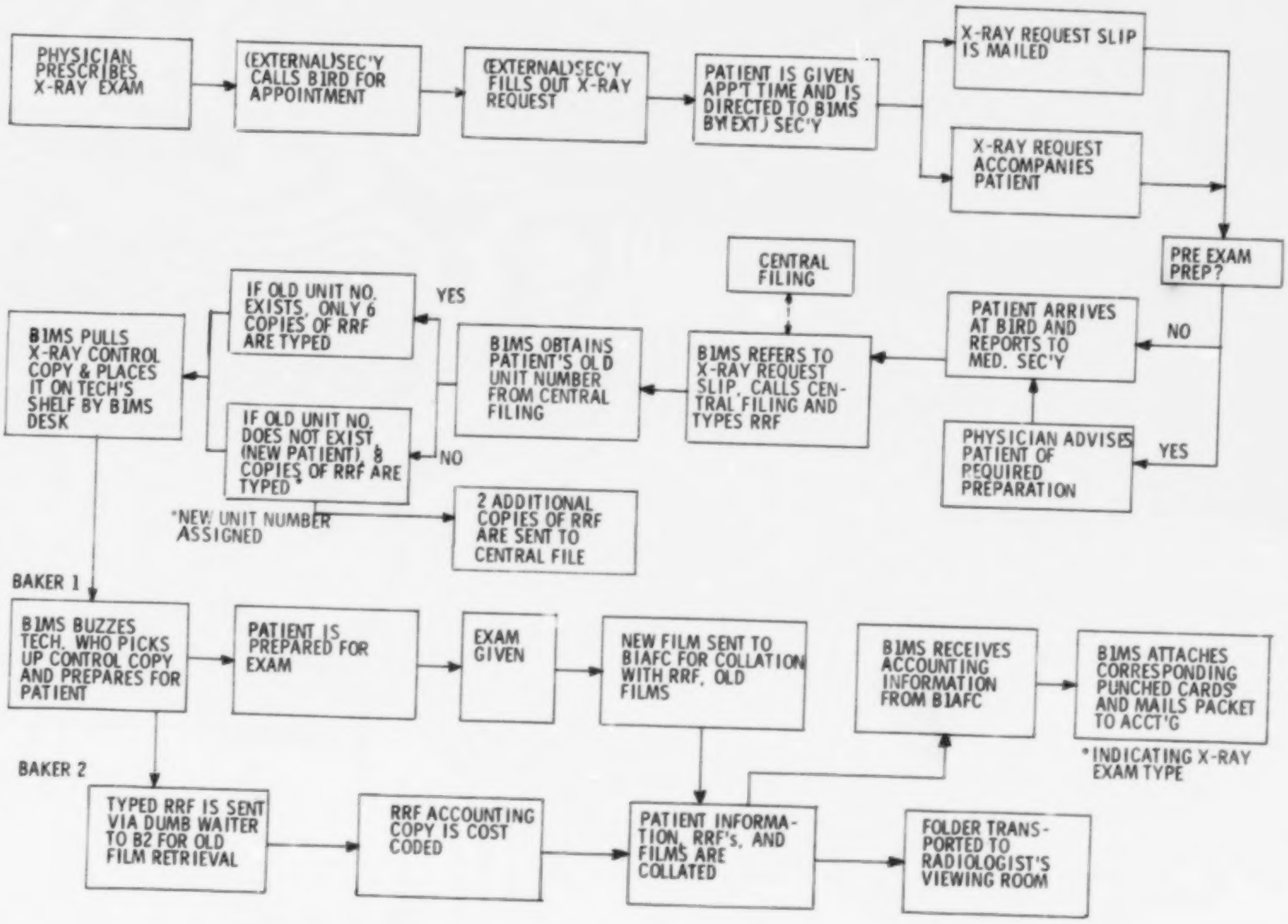

PHYSICIAN PRESCRIBES X-RAY EXAM
(EXTERNAL)SEC'Y CALLS BIRD FOR APPOINTMENT
(EXTERNAL)SEC'Y FILLS OUT X-RAY REQUEST
PATIENT IS GIVEN APP'T TIME AND IS DIRECTED TO BIMS BY(EXT.) SEC'Y
X-RAY REQUEST SLIP IS MAILED
X-RAY REQUEST ACCOMPANIES PATIENT
PRE EXAM PREP?
NO
YES
PATIENT ARRIVES AT BIRD AND REPORTS TO MED. SEC'Y
PHYSICIAN ADVISES PATIENT OF PEQUIRED PREPARATION
CENTRAL FILING
BIMS REFERS TO X-RAY REQUEST SLIP, CALLS CENTRAL FILING AND TYPES RRF
BIMS OBTAINS PATIENT'S OLD UNIT NUMBER FROM CENTRAL FILING
YES
IF OLD UNIT NO. EXISTS, ONLY 6 COPIES OF RRF ARE TYPED
NO
IF OLD UNIT NO. DOES NOT EXIST, (NEW PATIENT), 8 COPIES OF RRF ARE TYPED*
*NEW UNIT NUMBER ASSIGNED
2 ADDITIONAL COPIES OF RRF ARE SENT TO CENTRAL FILE
BIMS PULLS X-RAY CONTROL COPY & PLACES IT ON TECH'S SHELF BY BIMS DESK
BAKER 1
BIMS BUZZES TECH. WHO PICKS UP CONTROL COPY AND PREPARES FOR PATIENT
PATIENT IS PREPARED FOR EXAM
EXAM GIVEN
NEW FILM SENT TO BIAFC FOR COLLATION WITH RRF, OLD FILMS
BIMS RECEIVES ACCOUNTING INFORMATION FROM BIAFC
BIMS ATTACHES CORRESPONDING PUNCHED CARDS* AND MAILS PACKET TO ACCT'G
*INDICATING X-RAY EXAM TYPE
BAKER 2
TYPED RRF IS SENT VIA DUMB WAITER TO B2 FOR OLD FILM RETRIEVAL
RRF ACCOUNTING COPY IS COST CODED
PATIENT INFORMATION, RRF's, AND FILMS ARE COLLATED
FOLDER TRANSPORTED TO RADIOLOGIST'S VIEWING ROOM

Figure 6. Baker-1 (Private Ambulatory) Examination Sequence

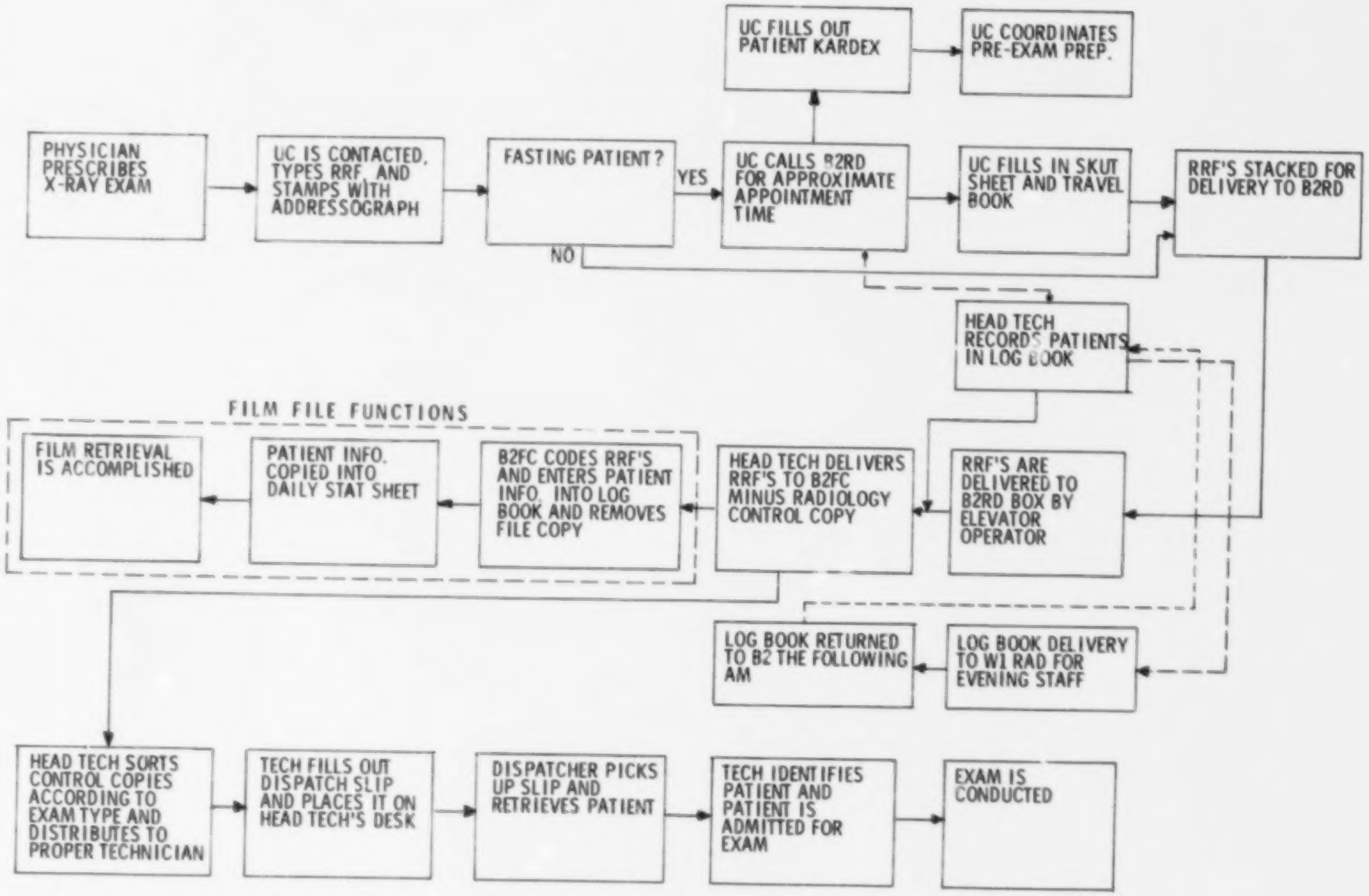

PHYSICIAN PRESCRIBES X-RAY EXAM
UC IS CONTACTED, TYPES RRF, AND STAMPS WITH ADDRESSOGRAPH
FASTING PATIENT?
YES
NO
UC CALLS B2RD FOR APPROXIMATE APPOINTMENT TIME
UC FILLS OUT PATIENT KARDEX
UC COORDINATES PRE-EXAM PREP.
UC FILLS IN SKUT SHEET AND TRAVEL BOOK
RRF'S STACKED FOR DELIVERY TO B2RD
HEAD TECH RECORDS PATIENTS IN LOG BOOK
RRF'S ARE DELIVERED TO B2RD BOX BY ELEVATOR OPERATOR
HEAD TECH DELIVERS RRF'S TO B2FC MINUS RADIOLOGY CONTROL COPY
FILM FILE FUNCTIONS
B2FC CODES RRF'S AND ENTERS PATIENT INFO. INTO LOG BOOK AND REMOVES FILE COPY
PATIENT INFO. COPIED INTO DAILY STAT SHEET
FILM RETRIEVAL IS ACCOMPLISHED
LOG BOOK DELIVERY TO W1 RAD FOR EVENING STAFF
LOG BOOK RETURNED TO B2 THE FOLLOWING AM
HEAD TECH SORTS CONTROL COPIES ACCORDING TO EXAM TYPE AND DISTRIBUTES TO PROPER TECHNICIAN
TECH FILLS OUT DISPATCH SLIP AND PLACES IT ON HEAD TECH'S DESK
DISPATCHER PICKS UP SLIP AND RETRIEVES PATIENT
TECH IDENTIFIES PATIENT AND PATIENT IS ADMITTED FOR EXAM
EXAM IS CONDUCTED

Figure 7. Baker-2 (Inpatient) Examination Sequence

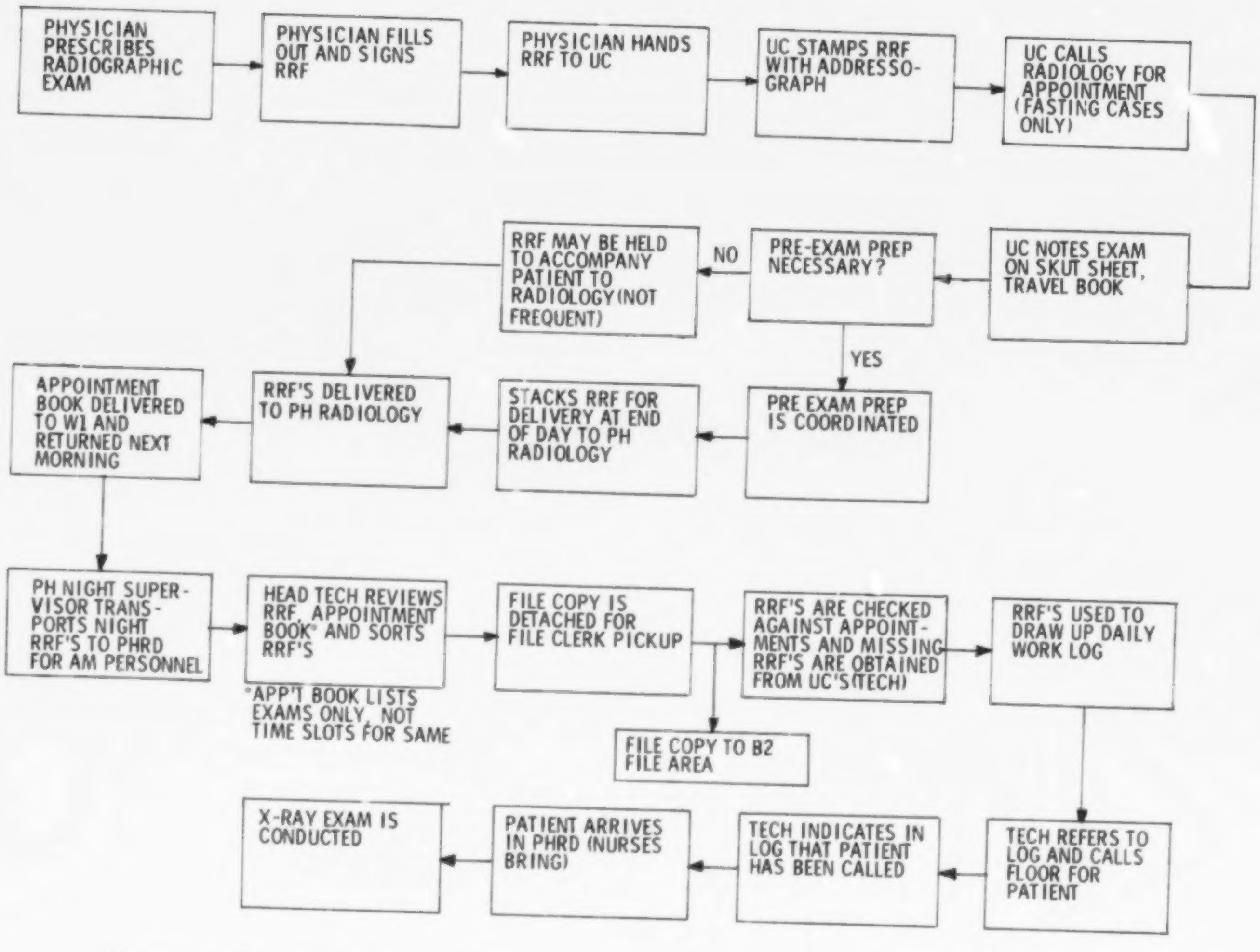
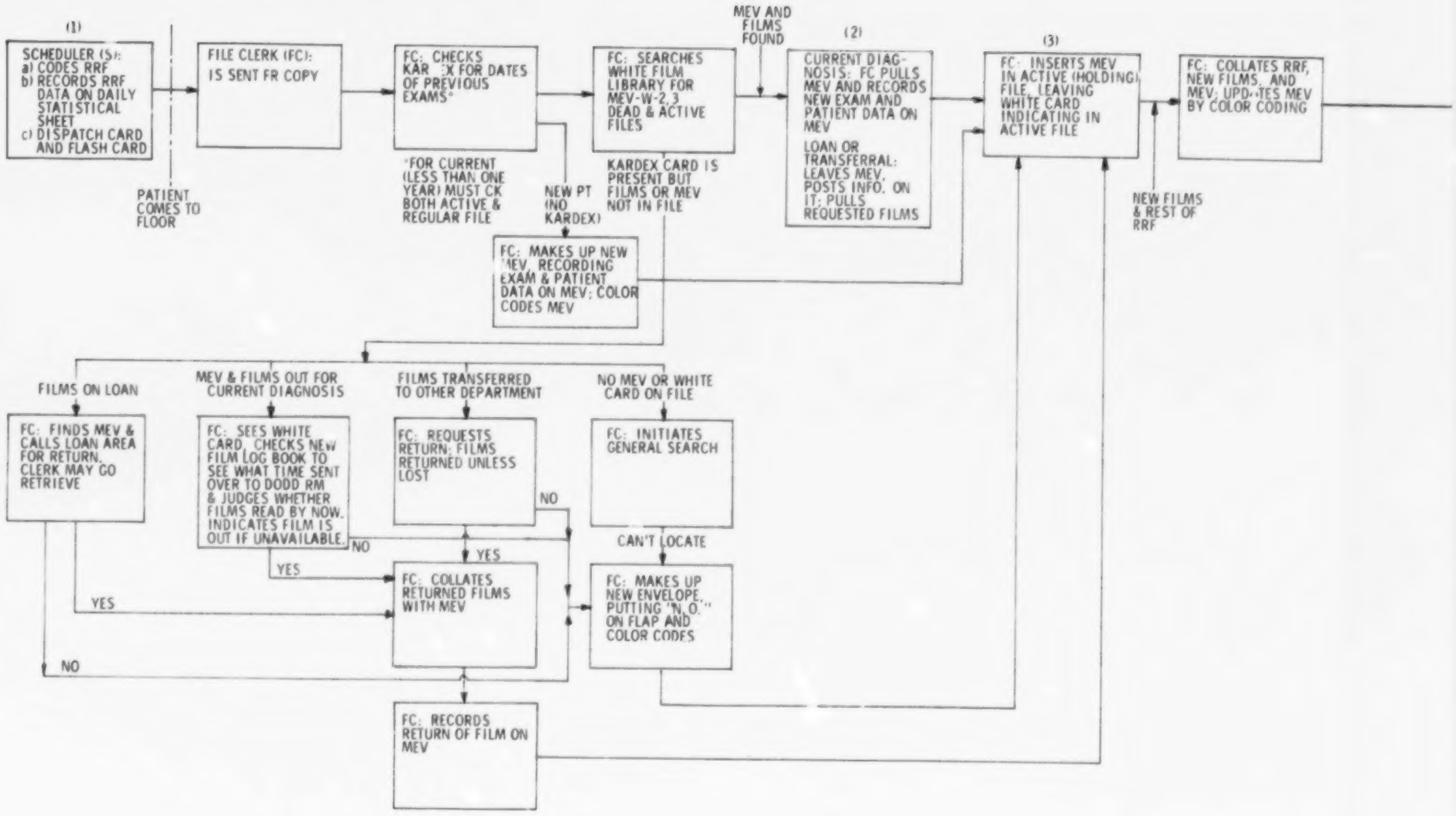
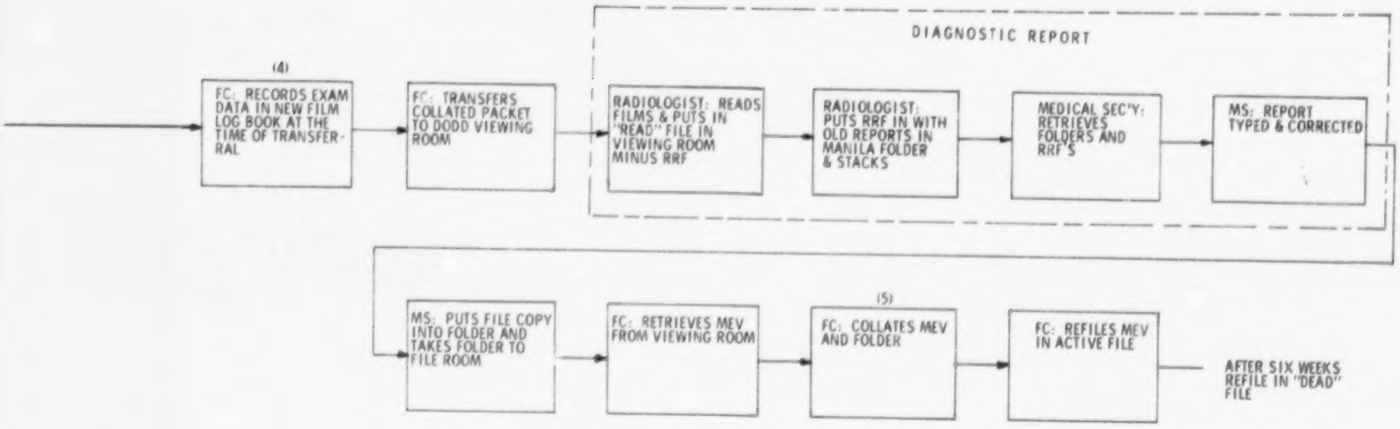

PHYSICIAN PRESCRIBES RADIOGRAPHIC EXAM
PHYSICIAN FILLS OUT AND SIGNS RRF
PHYSICIAN HANDS RRF TO UC
UC STAMPS RRF WITH ADDRESSO-GRAPH
UC CALLS RADIOLOGY FOR APPOINTMENT (FASTING CASES ONLY)
UC NOTES EXAM ON SKUT SHEET, TRAVEL BOOK
PRE-EXAM PREP NECESSARY?
NO
RRF MAY BE HELD TO ACCOMPANY PATIENT TO RADIOLOGY (NOT FREQUENT)
YES
PRE EXAM PREP IS COORDINATED
STACKS RRF FOR DELIVERY AT END OF DAY TO PH RADIOLOGY
RRF'S DELIVERED TO PH RADIOLOGY
APPOINTMENT BOOK DELIVERED TO W1 AND RETURNED NEXT MORNING
PH NIGHT SUPER-VISOR TRANS-PORTS NIGHT RRF'S TO PHRD FOR AM PERSONNEL
HEAD TECH REVIEWS RRF, APPOINTMENT BOOK* AND SORTS RRF'S
*APP'T BOOK LISTS EXAMS ONLY, NOT TIME SLOTS FOR SAME
FILE COPY IS DETACHED FOR FILE CLERK PICKUP
FILE COPY TO B2 FILE AREA
RRF'S ARE CHECKED AGAINST APPOINT-MENTS AND MISSING RRF'S ARE OBTAINED FROM UC'S (TECH)
RRF'S USED TO DRAW UP DAILY WORK LOG
TECH REFERS TO LOG AND CALLS FLOOR FOR PATIENT
TECH INDICATES IN LOG THAT PATIENT HAS BEEN CALLED
PATIENT ARRIVES IN PHRD (NURSES BRING)
X-RAY EXAM IS CONDUCTED

Figure 8. Phillips House (Inpatient) Examination Sequence


(1)
SCHEDULER (S): a) CODES RRF b) RECORDS RRF DATA ON DAILY STATISTICAL SHEET c) DISPATCH CARD AND FLASH CARD
PATIENT COMES TO FLOOR
FILE CLERK (FC): IS SENT FR COPY
FC: CHECKS KARDEX FOR DATES OF PREVIOUS EXAMS*
*FOR CURRENT (LESS THAN ONE YEAR) MUST CK BOTH ACTIVE & REGULAR FILE
NEW PT (NO KARDEX)
FC: MAKES UP NEW MEV, RECORDING EXAM & PATIENT DATA ON MEV; COLOR CODES MEV
FC: SEARCHES WHITE FILM LIBRARY FOR MEV-W-2,3 DEAD & ACTIVE FILES
KARDEX CARD IS PRESENT BUT FILMS OR MEV NOT IN FILE
MEV AND FILMS FOUND
(2)
CURRENT DIAGNOSIS: FC PULLS MEV AND RECORDS NEW EXAM AND PATIENT DATA ON MEV
LOAN OR TRANSFERRAL: LEAVES MEV, POSTS INFO. ON IT; PULLS REQUESTED FILMS
(3)
FC: INSERTS MEV IN ACTIVE (HOLDING) FILE, LEAVING WHITE CARD INDICATING IN ACTIVE FILE
NEW FILMS & REST OF RRF
FC: COLLATES RRF, NEW FILMS, AND MEV; UPDATES MEV BY COLOR CODING
FILMS ON LOAN
FC: FINDS MEV & CALLS LOAN AREA FOR RETURN. CLERK MAY GO RETRIEVE
MEV & FILMS OUT FOR CURRENT DIAGNOSIS
FC: SEES WHITE CARD, CHECKS NEW FILM LOG BOOK TO SEE WHAT TIME SENT OVER TO DODD RM & JUDGES WHETHER FILMS READ BY NOW. INDICATES FILM IS OUT IF UNAVAILABLE.
FILMS TRANSFERRED TO OTHER DEPARTMENT
FC: REQUESTS RETURN; FILMS RETURNED UNLESS LOST
NO MEV OR WHITE CARD ON FILE
FC: INITIATES GENERAL SEARCH
NO
NO
YES
YES
YES
CAN'T LOCATE
FC: COLLATES RETURNED FILMS WITH MEV
FC: MAKES UP NEW ENVELOPE, PUTTING "N.O." ON FLAP AND COLOR CODES
NO
FC: RECORDS RETURN OF FILM ON MEV


DIAGNOSTIC REPORT
(4)
FC: RECORDS EXAM DATA IN NEW FILM LOG BOOK AT THE TIME OF TRANSFERRAL
FC: TRANSFERS COLLATED PACKET TO DODD VIEWING ROOM
RADIOLOGIST: READS FILMS & PUTS IN "READ" FILE IN VIEWING ROOM MINUS RRF
RADIOLOGIST: PUTS RRF IN WITH OLD REPORTS IN MANILA FOLDER & STACKS
MEDICAL SEC'Y: RETRIEVES FOLDERS AND RRF'S
MS: REPORT TYPED & CORRECTED
MS: PUTS FILE COPY INTO FOLDER AND TAKES FOLDER TO FILE ROOM
FC: RETRIEVES MEV FROM VIEWING ROOM
(5)
FC: COLLATES MEV AND FOLDER
FC: REFILES MEV IN ACTIVE FILE
AFTER SIX WEEKS REFILE IN "DEAD" FILE

(1) a. EXAM CODE; COST CENTER; DATE; CLINIC, WARD, OR STAFF PATIENT SEQUENCE NO. FROM STATISTICS SHEET
    b. NAME, UNIT NO., TYPE EXAM(S), NO. OF EXAMS, EXAM CODE, PATIENT SOURCE

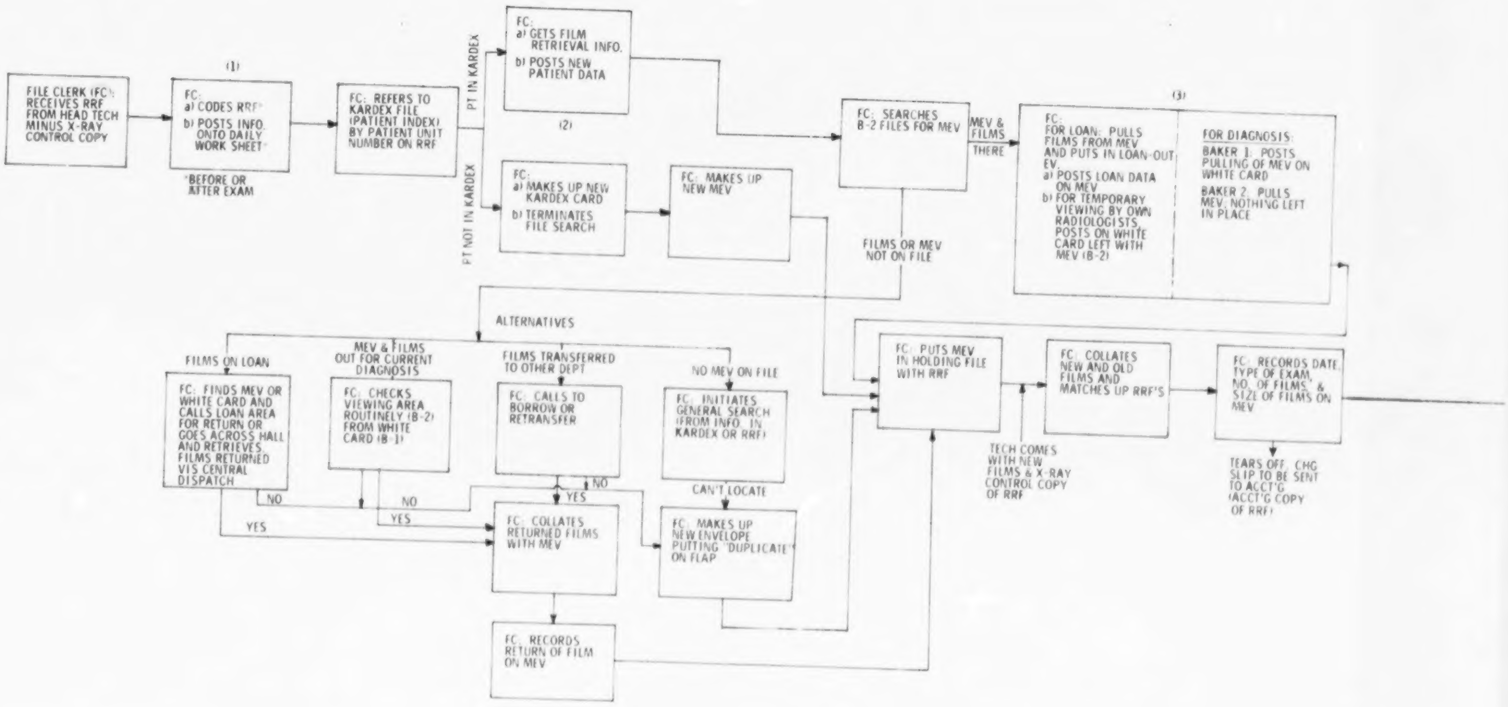
(2) DATE, NO. OF FILMS, TYPE OF EXAM, PATIENT ORIGIN

(3) WHITE CARD DATA: a. DATE LEFT; b. TYPE EXAMS; c. DESTINATION (CLINIC OR WARD); d. NAME & UNIT NO.; e. DATE RETURNED

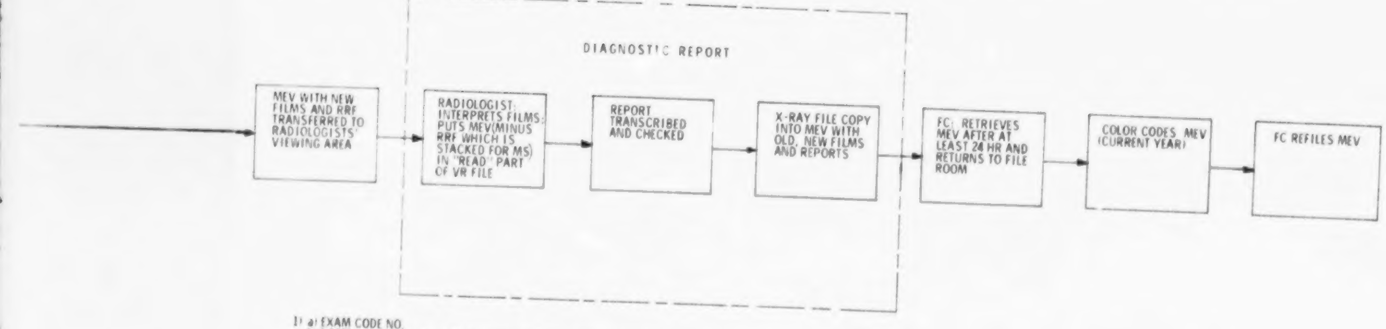
(4) NAME, UNIT NO., PATIENT SOURCE, ANATOMICAL CATEGORY, TIME COLLATED PACKET TAKEN TO CONFERENCE ROOM

(5) NAME, YEAR, EXAM DATE RECORDED ON KARDEX FROM DAY SHEETS

Figure 9. White Film File and Reporting Functions


FILE CLERK (FC): RECEIVES RRF FROM HEAD TECH MINUS X-RAY CONTROL COPY
(1)
FC: a) CODES RRF* b) POSTS INFO. ONTO DAILY WORK SHEET*
*BEFORE OR AFTER EXAM
FC: REFERS TO KARDEX FILE (PATIENT INDEX) BY PATIENT UNIT NUMBER ON RRF
PT IN KARDEX
PT NOT IN KARDEX
FC: a) GETS FILM RETRIEVAL INFO. b) POSTS NEW PATIENT DATA
(2)
FC: a) MAKES UP NEW KARDEX CARD b) TERMINATES FILE SEARCH
FC: MAKES UP NEW MEV
FC: SEARCHES B-2 FILES FOR MEV
MEV & FILMS THERE
FILMS OR MEV NOT ON FILE
(3)
FC: FOR LOAN: PULLS FILMS FROM MEV AND PUTS IN LOAN-OUT EV. a) POSTS LOAN DATA ON MEV b) FOR TEMPORARY VIEWING BY OWN RADIOLOGISTS, POSTS ON WHITE CARD LEFT WITH MEV (B-2)
FOR DIAGNOSIS: BAKER 1: POSTS PULLING OF MEV ON WHITE CARD BAKER 2: PULLS MEV; NOTHING LEFT IN PLACE
ALTERNATIVES
FILMS ON LOAN
MEV & FILMS OUT FOR CURRENT DIAGNOSIS
FILMS TRANSFERRED TO OTHER DEPT
NO MEV ON FILE
FC: FINDS MEV OR WHITE CARD AND CALLS LOAN AREA FOR RETURN OR GOES ACROSS HALL AND RETRIEVES. FILMS RETURNED VIS CENTRAL DISPATCH
FC: CHECKS VIEWING AREA ROUTINELY (B-2) FROM WHITE CARD (B-1)
FC: CALLS TO BORROW OR RETRANSFER
FC: INITIATES GENERAL SEARCH (FROM INFO. IN KARDEX OR RRF)
NO
YES
NO
YES
YES
NO
CAN'T LOCATE
FC: COLLATES RETURNED FILMS WITH MEV
FC: MAKES UP NEW ENVELOPE PUTTING "DUPLICATE" ON FLAP
FC: RECORDS RETURN OF FILM ON MEV
FC: PUTS MEV IN HOLDING FILE WITH RRF
TECH COMES WITH NEW FILMS & X-RAY CONTROL COPY OF RRF
FC: COLLATES NEW AND OLD FILMS AND MATCHES UP RRF'S
FC: RECORDS DATE, TYPE OF EXAM, NO. OF FILMS, & SIZE OF FILMS ON MEV
TEARS OFF CHG SLIP TO BE SENT TO ACCT'G (ACCT'G COPY OF RRF)

verso blank


DIAGNOSTIC REPORT
MEV WITH NEW FILMS AND RRF TRANSFERRED TO RADIOLOGISTS' VIEWING AREA
RADIOLOGIST: INTERPRETS FILMS; PUTS MEV(MINUS RRF WHICH IS STACKED FOR MS) IN "READ" PART OF VR FILE
REPORT TRANSCRIBED AND CHECKED
X-RAY FILE COPY INTO MEV WITH OLD, NEW FILMS AND REPORTS
FC: RETRIEVES MEV AFTER AT LEAST 24 HR AND RETURNS TO FILE ROOM
COLOR CODES MEV (CURRENT YEAR)
FC REFILES MEV

1) a) EXAM CODE NO.
b) NAME, UNIT NO., TYPE OF EXAM(S), CODE(S), PATIENT SOURCE

2) FILM RETRIEVAL: YEAR OF LAST EXAM., UNIT NO.
NEW PATIENT DATA: DATE OF EXAM (DAY, MONTH, YEAR)
MAKES NEW KARDEX CARD: REFERS TO CASO CARD FILE

3) LOAN DATA: 1 ON MEV: DATE OF LOAN, NAME AND LOCATION OF BORROWER; UNIT NO. AND NUMBER OF FILMS LOANED, DATE RETURNED
2 ON WHITE CARD (B-2): DATE LOANED OUT, UNIT NO. (GOES TO VIEWING ROOM)
TRANSFERRALS: ON MEV: LOCATION (NEW FILE AREA); DATE TRANSFERRED

Figure 10. Baker Film File and Reporting Functions

3.3 PORTABLE X-RAY SERVICE

White-1, White-2, and Baker-2 radiology have the facilities for taking care of portable X-ray examinations. The medical secretary in each case receives a call from the floor or operating room requesting a portable examination and is given pertinent patient information. Cardiac, operating room, intensive care, or recovery are automatically regarded as cases necessitating a portable. Other requests may have to be approved by the radiologist through discussion with attending personnel concerning the condition of the patient. Such selectivity needs to be exerted since examinations by portable units result in poorer quality images than those performed on regular machines.

On White-1, the appropriate file room may then be called for retrieval of the patient's old records. The medical secretary may then notify the technologist assigned to portables of the examination request. In addition, (a) on White-1 the technologist may refer to a list of "portable examinations to be conducted", and (b) on Baker the technologist may refer to a stack of "portable RRF's" left for the day by the Baker-2 file clerk or a surgery schedule indicating where portables will most likely be needed. Along with the pertinent patient information, he takes the portable unit to the floor or operating room, picks up the RRF at the nursing station, conducts the examination, and returns to the respective radiology department with films and forms. On White-1 the medical secretary logs the patient in from information on the RRF; on White-2 the scheduler, and on Baker 2 the file clerk codes the RRF (which is then used in old film and report retrieval). Then the films are taken to the corresponding dark room technicians for processing. On White-1 and Baker-2, the technician quality checks the films with approval of the radiologist who then views them in conjunction with any of the patient's old films and reports. On White-2 the films are checked by quality control, are marked as portables and for the date and time taken, and are then read by the radiologist. The floor personnel receive a "stat reading" for the "emergency cases" and/or get the medical records copy from the RRF to put into the patient's chart.

3.4 NEURORADIOLOGY

Neuroradiology handles about 2,000 cases per year. These consist only of neuromedical or neurosurgical inpatients, with the most frequently conducted examinations being cerebral angiography, pneumography, and myelography. The specific radiologic procedure needed for a patient is decided by his physician in consultation with either of the two neuroradiologists. An appointment is made about 1-1/2 weeks in advance for the neuroradiology suites on White-2 by the resident. At the scheduled time the patient with his medical chart and RRF is retrieved via dispatcher. As the examination progresses, the films are developed on White-2 X-omats, and the RRF is filled out and taken to the neuro-filing area for retrieval of old films by the neuro-secretary. After the examination is completed, the new films, old films, and medical chart (containing clinical information) are handcarried to viewers in one of the staff neuroradiologist's offices for diagnosis. The medical secretary types the indicated readings onto the RRF and disperses the various copies in the normal fashion. Then the films are removed and filed according to the following procedure: (1) films up to 30 days old are arranged in an "active file" in one of the staff radiologist's offices; (2) films one month to two years old are filed alphabetically in the neurology section in the Baker-2 file room (except for myelograms which are placed in the master folder in either the White-2 or Baker-2 main film file depending on where the patient was admitted); and (3) films three to five years old are stored in the White-14 file area.

3.5 CINES

A total of nearly 10,000 cine examinations have been conducted since the technique was initiated in 1961, the current case load being around 1300 cines per year. More than half of the examinations given have to do with urology and cystogram work, with most of the patients coming from pediatric and private urology or private and house orthopedics. A request for a cine examination is expressed verbally rather than by filling out the standard RRF. All examinations are scheduled for the Satellite Room on White-2 by the cine technologist, with most of the morning set for chest fluoroscopies and the afternoon for urology. The examinations are conducted by the radiologist assigned to Baker-1 for that day. The White-2 receptionist pages the radiologist when the patient arrives, and, after the examination has been completed, the films are developed in a special dark room on White-2. The radiologist then views the films with the aid of a projector and may refer to old cines or old X-ray films in making his diagnosis. The dictated diagnosis is then transcribed onto the standard RRF by the medical secretary and dispersed. Cine storage is monitored by the technologist and his assistant, and special interest films, follow-up and post-surgical cases, and film up to 30 days old are filed in racks along the walls in the projection room. The next oldest rolls are filed on White-2 and White-3A, and the oldest are on White-14 and then Baker-2. The information written onto the film containers consists of the date, the name and unit number of the patient, the kind of examination, and the requesting doctor's name or service. If a physician wishes to borrow certain films, he may do so by signing them out in the "Loan-out Log Book".

3.6 NUCLEAR RADIOLOGY

Diagnostic nuclear medicine handles 1500 to 1700 cases per year. These consist mainly of inpatients, with the major types of scans being brain, lung and liver. It is imperative that all examinations involving radioisotopes be prescheduled to coordinate them with the effective period of available isotopes, some of which may have a half-life of only a few hours. To secure an appointment for his patient, the physician (or nurse or ward secretary upon direction from the physician) calls the isotope laboratory technologist on White-2 for an appointment. The technologist will refer to the scheduling book for a specific time and will obtain the following information form the requester: patient's name, unit number, floor location, and type of scan. Some examinations may be quite lengthy, taking three to four hours at 24-hour intervals for several days. At the same time arrangements for the taking of certain conventional X-rays may need to be made; e.g., a chest X-ray may be necessary in conjunction with a lung scan. It is required that the RRF be in the laboratory before premedication or injection may be administered. However, this rule may be waived in emergency cases (which occur two to three times per week) if the radiologist obtains pertinent medical information from the referring physician verbally. The scans are produced on a machine adapted for polaroid film in the Nuclear Radiology section. In making his diagnosis from the scan, the radiologist occasionally requests previous radiologic films and readings together with any currently taken X-ray films, and he records his interpretation manually on the back of the polaroid scan envelope. From this, the medical secretary transcribes the reading onto the patient's RRF and disperses the respective copies in the routine manner.

3.7 ANGIOGRAPHY

The major portion of angiographic studies consists of abdominal angiograms and peripheral vascular studies with the Baker service supplying most of the patients (from an annual case load of about 1300). To schedule a patient for an examination, the attending physician calls the angiography medical secretary about two days in advance of the desired date. The medical secretary checks her appointment book (a maximum of three examinations per day are scheduled) and records the patient's name and floor location, the doctor's name, clinical information, and the type of examination requested.

At the designated time the Angiography nurse or technologist notifies the floor, and a dispatcher is sent to bring the patient together with his medical chart and the RRF to the Angiography room on White-2. A staff radiologist conducts examinations for all private patients, while a resident does the non-private ones. Normally, during the course of each study, three rolls of angiographic film are exposed and viewed. As the examination progresses, the films are brought by the technologist to the main processing room (White-2) for development. These take precedence over any other submitted films. The technologist then brings the films to the Angiography office where they are reviewed on specially adapted viewers by the staff radiologist and two residents, along with old films and reports. The report is dictated, and the medical secretary transcribes the diagnosis onto the RRF and disperses the copies in the routine manner (after the X-ray file copy is first duplicated for storage in the Angiography office). The films themselves are stored in boxes having on them the patient's name, unit number, date and angiography number (a log number from the angiography scheduling book); the boxes are color coded with tapes

3-26
7-R

to represent the month and year of the examination. These boxes are filed serially as studies are done throughout the year, and they are stored in various areas (e.g., Angiography office, White-2 file room, White-3A, Baker-2). The total film collection includes all examinations back to the inception of angiographic procedures (1958) and is handled by the Angiography medical secretary. In addition, the respective file area (White-2, Baker, Phillips House) makes up a master folder for each patient to contain any conventional X-ray and/or the X-ray file copy of the RRF. If a doctor wants to borrow an angiography film, he may call or write the Angiography office or sign the film out himself in a "Loan-out Log Book" recording the date, his name, and destination.

3.8 DIAGNOSTIC RADIOLOGY BILLING AND ACCOUNTING PROCEDURES

Billing for the services rendered a patient in the course of an X-ray examination is divided into two separate areas:

- Billing for professional services
- Billing for hospital services rendered in conjunction with X-ray procedures

Professional Services

Professional service billing is one of several functions performed by the Radiological Associates (RA) group, a legal entity created by and consisting of the staff radiologists which performs various administrative functions of the department. The RA is staffed by an administrator and several assistants and is responsible for all patient and insurance carrier billings for professional radiological services performed by the staff.

The operation of RA is best described by the inputs to and outputs from the group: Upon admission to the hospital, a patient record and identifier card (CASO card) is generated in the Admissions Office. A copy of this is sent to the RA office. The key pieces of information included on the in-patient card are:

Patient hospital unit number
Patient name
Patient guarantor
Patient address
Admission date

Blue Shield number
    Date of birth

Medicare number
    Diagnosis
    Med-X number

After the patient has been X-rayed, the X-ray control copy of the RRF as well as a copy of the diagnostic report is also sent to RA. At this point the CASO card data is collated with the X-ray examination and examination code number (from a standard code and rate schedule) which has been taken from the X-ray control copy of the RRF. This data is then used for generating three punched cards for each patient, to be used in the billing process. The cards contain:

- CASO card data, as described above
- Examination and code number
- Patient name and address

These cards are then processed on an IBM 360/20 computer which provides a billing form (for professional services) to be sent directly to private patients who are instructed to pay Radiological Associates directly. For third party payments, the appropriate Blue Shield or Medicare claim form is sent directly to the patient's insurance carrier (Massachusetts Medical Service). Upon receipt of payment, another punched card is generated and processed with the patient's previous cards to record that the service fee has been paid.

Although the above procedure pertains to inpatient procedures, the same sequence applies to clinic (White-2) and private ambulatory patients (Baker-1). In this case, however, it is necessary to obtain all the required patient data from the Outpatient Radiological Request form. If this form is not completely and accurately filled out at the point of patient origination, it is necessary for RA personnel to retrieve the required patient data from the hospital Medical Records section.

Radiological Associates also does patient billing for therapeutic X-ray procedures. In addition, it generates miscellaneous statistics such as gross charges and receipts for the seven radiological services (private ambulatory - Baker-1, Clinics, White-2, Emergency Ward, Therapy, Private Inpatients - Baker-2, Phillips House) and periodic listings of accounts receivable, etc.

Hospital Services

Billing and accounting for hospital service charges are performed in two separate areas within the hospital: Hospital Tabulating, located on the basement level of the Mosley Building, and Private Ambulatory Accounting and Billing, located on Mosley-2. The former is responsible for inpatient and clinic patient billing for all hospital services, including X-ray; the latter is concerned with only private ambulatory patients. Hospital Tabulating uses punched card data and automatic data processing for patient billing purposes. Hospital service charge statements are generated by computer printer and sent to the patient at the time of discharge. For specific radiological service charges, billing data is taken from the accounting copy of the radiological request form, which is sent upon completion of the examination from the X-ray film sorting area either to Mosley-2 or Hospital Tabulating, depending upon the type of patient. Private ambulatory patient billing (Mosley-2) is done manually, the patient being sent an itemized, typed bill for all hospital services rendered. The typed bill is composed of five copies, the first sent to the patient and the remaining four filed by patient name to be used for sequential billing.

SECTION 4

NEEDS AND REQUIREMENTS WITHIN MGH DIAGNOSTIC RADIOLOGY

The discussion in Section 2 treated the goals of MGH Radiology and, in so doing, illustrated some of the department requirements to be met in attaining these goals. The department is continually concerned with current analyses of their needs, as evidenced by the activities of the MGH Radiology Planning Committee, the Executive Committee, the Educational Committee, the Staff, and MGH Radiological Associates. These groups are concerned with the policies and equipment needs of the department. In contrast, the present study has concentrated on the more detailed aspects of department operation and the furnishing of radiological services to the patient. In the process, certain organizational patterns have suggested themselves, and these are commented upon elsewhere. In the following discussion, however, we list the more detailed requirements encountered in moving a patient through the diagnostic radiology system at MGH.

In itemizing system requirements as follows, we have chosen the method of listing what items of action must occur at various points in the time progression of a patient through the system. At each point the questions of what, when, where, how, why, and extent are answered where applicable.

(1) X-ray patient must be identified at origination point.

Where: Ward, clinic, emergency, overnight ward

How: Patient name, hospital unit number, type of examination required, age, sex, ward or clinic address. The following information is not necessary in this part of the patient identification process, but is usually available at the patient origination point: home address, physical status, referring private physician (where applicable), any prior films

Why: Identification and verification

(2) Resources must be allocated for examination (i.e., examination must be scheduled).

What: Time, examination room, radiologist, technician, dispatch personnel

Where: In location where resource availability is monitored

How: Manually, by scheduler aware of resources available, or automatically

When: Prior to examination

Extent: Dependent upon type of examination

(3) Patient must be prepared for examination.

Where: At origination point (on floor) or in X-ray

Why: Requirements associated with specific examination

When: Prior to examination

Extent: Dependent upon examination; varies from none or a simple clothing change to fasting and more elaborate procedures

(4) Patient must be brought to machine.*

When: Prior to examination

Where: To radiology from patient origination point

How: By dispatch personnel (wheelchair, guerney) or by walking (ambulatory)

(5) Patient must be identified upon arrival at machine.

When: Prior to examination

Where: In examination area, or a central control area

How: By matching patient information at examination site with information accompanying patient

Why: To prevent unnecessary procedure; to assure correspondence of patient with specified examination

(6) Examination must be performed.

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*Opposite is true in case of portable X-rays.

(7) X-ray films must be processed.

When: As soon as possible after examination prior to patient return to origination point

Where: Processing facility in examination area

How: Dependent upon examination and/or film; most commonly by X-omat processor

(8) New films must be quality checked.

When: As soon as possible after developing, before patient return to origination point

Where: New film developing facility

How: By visual observation, requiring technologist and/or radiologist

Why: To assure interpretability by radiologist

(9) Patient is dismissed from department and sent back to origination point.

Where: From the radiographic room or central control area

When: After new films deemed satisfactory

How: By indication from radiologist or technician

(10) New films must be brought together with patient descriptors (Radiology Request Form), old films, and old reports (wherever and whenever possible).

What: Old films, new films, RRF

When: After examination, before interpretation by radiologist or available before start of examination to aid technologist and/or radiologist in conduct of current examination

Where: Collating area (film filing or processing area)

How: Manually

Why: To match patient with radiograph; to aid in diagnosis; to aid in conduct of current examination

(11) Radiologist interprets new radiographs (with old for comparison purposes) and records diagnosis.

When: After examination, radiograph quality checks, and collation of old and new films and patient data (RRF)

Where: Viewing area

How: Vocal transcription; automatically

Extent: Dependent upon examination and/or radiologist

(12) Diagnosis must be converted to a form convenient for radiologist's review.

When: After verbalization of report

Where: In a location close (in time) to the radiologist

How: Manual transcription, automatic display or replay

(13) Displayed diagnosis (i.e., interpretation of films) is reviewed, edited, and approved by radiologist.

When: After processing (transcribing or computer processing)

Where: Viewing area

Extent: Interpretations by residents are reviewed jointly by the resident and a staff radiologist. Exceptions may occur in the case of interpretations by senior residents. All cases involving third-party billings (e.g., Medicare or Blue Shield) must be reviewed by a staff member.

Why: To ensure accuracy and satisfy third-party billing requirements

(14) Diagnostic reports must be disseminated.

What: One copy each destination

When: Upon radiologist's approval

Where: X-ray file
Medical records
(Patient's floor or clinic)
(Referring physician)
Hospital billing
Professional billing } Patient identification data mentioned in step (1) required here for administrative and billing purposes

How: Manually or automatically

(15) All patient data must be identified, collated, and filed.

What: Old, new films; old, new reports

When: After diagnosis and reporting procedure

Where: Filing area (most probable)

How: Manually by color code, unit number, etc.

Why: Future patient diagnostic requirements; legal, teaching and research requirements

(16) Films and reports must be available on demand for current diagnostic and teaching procedures and for review by referring physicians.

The above steps represent the requirements to be met in moving a patient through the diagnostic radiology system. They imply interactions among patient, technicians, clerical, and dispatch personnel and radiologist, and they indicate the nature of information and information flow necessary in the diagnostic X-ray process. The following section is a critical discussion of the manner in which the present system at MGH meets these requirements. It also points out areas, through the use of substantiating data, where the application of automatic data processing techniques promises significant benefits in terms of increased efficiencies throughout the system.

SECTION 5

NEED FOR AUTOMATIC DATA PROCESSING WITHIN DIAGNOSTIC RADIOLOGY

Section 4 reviewed the procedural requirements which have to be met in moving a patient through the radiology system at MGH. The reader can see, in much greater detail, how these requirements are met by referring to the Appendix B and Section 3 where process sequence narrations and diagrams are presented for each of the five geographical areas comprising the Radiology Department at MGH. In each case it is apparent that there exist complex interactions of machines and processes involving verbal and written information, radiology personnel, X-ray films, and patients. If any one of these elements of the system fails to interact or to arrive at a predetermined point at a given time, delays arise, queuing begins, and system efficiency suffers.

5.1 GENERAL

Observation of the operations within Diagnostic Radiology revealed several areas where problems continually arise and the potential for improved operation is greatest. These areas include:

- Patient and resource scheduling
- Film filing, locating, and retrieval
- X-ray diagnosis reporting

In looking at each of these areas in detail, it is necessary to answer the questions of when, where, why, how, and to what extent system failures occur. In doing so we utilized the following sources of, and methods of gathering, information:*

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*This effort illustrated a practical difficulty encountered during the data gathering phase: The dynamic nature of the department organization and the periodic introduction of new procedural methods (e.g., patient scheduling) in striving for improved department operation present an ever-changing picture of the MGH Radiology environment. Our data portrays a period during which such changes were occurring and thus does not reflect the effects of these changes. It is necessary, however, that the introduction of new procedures be accompanied by the use of techniques to evaluate their effect on system operation. The tools used in this study are well suited to this type of continuing evaluation.

- Radiology department records, including:
    (1) Department statistics and management data
    (2) Subspecialty and subarea worksheets (statistics daysheets)
    (3) Patient dispatch data
    (4) X-ray film loan-out request sheets
- Interviews of department personnel, including radiologists, head technologists, technicians, clerks, nurses, schedulers, etc.
- On-site observations of system operation and personnel activities in the five geographical subareas of MGH Diagnostic Radiology
- On-site data collection by MGH and Honeywell personnel (room utilization, examination and patient stay times, etc.)
- Time-flow studies of the progression of the radiology request form through the system

It is evident that the greatest demands are placed upon the system during peak patient-load periods. The peak monthly periods were determined by subdepartment and subspecialty and are shown in Table 6, along with the months of minimum patient examination volume.

The system is also strained during normal patient load periods, particularly when the department resources are reduced in one form or another. Visible evidence of this occurred during the data gathering phase of this study (December 1968 through February 1969), when Hong Kong flu was prevalent in the Boston area. Many of the MGH radiology personnel were absent due to illness. The result was a reduction in the human resources of the department, an overburdening of the available staff, and an increase in patient queuing throughout the department. The same type of situation can occur, but to a lesser degree, when X-ray machine breakdown occurs. In this case, the material resources of the department are reduced. Patients scheduled for examination on that particular machine must be X-rayed on other units. Adequate provision must be made for this type of information to be fed back to patient origination points.

5.2 PATIENT SCHEDULING

The comments in the preceding paragraph apply particularly to the problem of patient scheduling. Since the patient scheduling procedures used during the late 1968-early 1969 time period in diagnostic radiology are described elsewhere, they will not be treated here. Instead, we shall present evidence of the inadequacy of the system in force at that time.

Table 6. Number of Examinations· Subspecialty and Departmental Breakdown on Monthly Basis (for fiscal year 1967-68) in Terms of Volume Handled

Month	Special Procedures				White-2	Baker-1	Baker-2	White-1	Phillips House
	Isotope	Neuro	Angio	Ci					
1967 Sept.	123	169	84	[illegible]	4, 736	1, 498	2, 263	4, 404	865
Aug.	146	175	79	9[illegible]	5, 033	1, 278	2, 279	4, 840	881
July	114	160	108	121	5, 013	1, 371	2, 483	5, 031	812
June	105	170	92	107	4, 784	1, 393	2, 377	4, 574	888
May	143	173	137	93	5, 184	1, 599	2, 722	4, 697	804
April	136	154	118	101	5, 155	1, 570	2, 575	4, 566	801
March	129	217	114	115	5, 161	1, 549	2, 496	4, 450	796
Feb.	122	176	88	96	4, 729	1, 537	2, 326	4, 219	814
1968 Jan.	140	166	115	110	4, 646	1, 465	2, 419	4, 707	975
Dec.	112	201	106	91	4, 032	1, 312	2, 123	4, 333	827
Nov.	131	164	141	112	4, 700	1, 618	2, 161	4, 287	807
Oct.	110	171	88	91	4, 926	1, 471	2, 150	4, 350	778
Average per Month	126	175	106	102	4, 842	1, 472	2, 365	4, 538	837
Deviation from Average									
+ Max	+20	+42	+35	+19	+342	+146	+357	+493	+138
- Min	-21	-21	-27	-13	-810	-194	-242	-319	- 59
Percent Deviation From Average									
Max %	16	24	33	19	7	10	15	11	16
Min %	17	12	25	13	17	13	16	7	7

Data and information on scheduling problems were collected in the following ways:

- Questionnaires to department schedulers
- Determination of patient waiting times within the department
- Interviews with department personnel

The scheduling questionnaire pointed up the following difficulties, in the order of their considered importance to the schedulers (the percentage figures included in some of the categories represent estimates on the part of various department personnel):

- Patient not ready at the appointed time for transport to Radiology (10-20 percent of the time)
- X-ray equipment failure
- Understaffing (personnel absences)
- Emergency patients (10-15 percent of total)
- Incomplete knowledge of patient's condition
- Variability of examination time
- Scheduling conflicts with other hospital services
- Patient cancellations (10 percent of the time)
- X-ray retakes required (5 percent of the time)
- Prolonged dispatch time
- Delay of radiological request form (RRF)
- Weather
- Examination room occupied for special procedure work

Determinations were also made of patient waiting times within White-2 radiology. These times were derived from a large sample of White-2 inpatients by noting both when the patient arrived in White-2 radiology and when he was returned to his ward floor after the examination. By subtracting the average time normally required for the particular examination from his total stay time, a rough estimate of total wait time is obtained. Patient arrival and departure times were obtained from the floor dispatch records which record patient's name and dispatcher's departure and return clock times for both retrieving and returning the patient. The wait times are listed in Appendix E. The reader should note the following qualifications which must be used in interpreting the data:

- Only inpatients were monitored. These generally represent a more incapacitated segment of the patient population (as opposed to clinic patients) and are not required to wait for word as to the necessity of X-ray retakes. Therefore, their wait times are probably less than that of the ambulatory (clinic) patient. "In" and "out" times of ambulatory patients are not recorded by the receptionist on White-2.
- Examination times for the sicker, bedridden types of patients tend to be longer than the averages. Thus, the tabulated waiting times may be longer than actually occurred in many of the cases.

The data does illustrate, however, that the typical inpatient spends a considerable portion of his time waiting for something to happen. This suggests that there may be room for improvement in information flow among technologists, schedulers, and nursing stations, so that patient waiting times within the radiology department could be reduced.

5.3 FILM FILING, RETRIEVAL, AND LIBRARYING

The film filing and librarying functions within MGH diagnostic radiology are complex systems incorporating different filing procedures carried out in several different areas. Several factors contribute to a lack of efficiency in the filing and librarying procedures. One of these is the physical separation of various interacting file areas -- determined both by the nature of the patient population as well as lack of centralized space. White Building patients' films are filed either on W2 (in an "inactive" or "active" file), W3 or W14. The B2 file area accommodates all hospital pediatrics cases, Phillips House, private ambulatory, and Baker inpatients, as well as the Neuroradiology film file (cf. Appendix C for description of present and proposed filing system layouts). Furthermore, file area space allocation has not kept pace with the ever increasing patient population. This increasing lack of space is reflected in the overflow of the various film files onto auxiliary tables, carts, and tops of file cabinets and is reflected in the constricted work areas for file room personnel within these file spaces. In addition, White and Baker are not exactly alike in their film filing and monitoring procedures, and this, together with a lack of intercommunication between them, hampers the efficient interchange of information when the need arises.

In analyzing specific procedures involved in actual film location and retrieval, many inefficiencies were seen. In the retrieval of a requested film, the file clerk makes references to the patient's name and unit number from a day sheet, a film room copy of the RRF, or a "request for X-ray films" form. These "old-film requests", for aid in diagnosis purposes, do not arrive evenly distributed in time. On B2, a pile of them arrive in the morning, and then an unpredictable amount come down during the day -- dependent on last-minute scheduling amendments. On W2, the arrival of the film request forms are correlated with the rate of arrival of patients to the X-ray floor for their examinations. And, of course, the requests for film loans may come at any time during the day in both areas. Therefore, except for film loans and for stat examinations, the film retrieval system seems generally based on a "first-come-first served" basis and not on immediacy of need (e.g., to coordinate with the radiologist's available consultation or reading time).

Having received a request for films, the file clerk first refers to the Patient Index File (PIF) to assess whether such films exist and if so, where they are located (going by the year of the last examination). This can be misleading, however, since very recently taken films may not yet be recorded here, and the film master envelope may be in another area than would be indicated by the last PIF entry. On B2 this might be in the viewing room file or a radiologist's file cart, etc. On W2 they may also be in the viewing room (which can first be ascertained by looking in a separate Log Book for that purpose). Furthermore, since in the W2 PIF only the year of the last examination is entered, in retrieving films of a current year the file clerk may have to check in several places in addition to the regular ones, the "6-week file" or the various "viewing room" files. For locating other "years" he may have to go to one of the three physically separate file areas (W2, W3, W14), and/or check the "holding files" for (a) returned films or (b) "film packets awaiting new films" or (c) "for films waiting to go out on loan", and may have to retrace his steps several times depending on the characteristics of incoming film requests.

The lack of additional information such as the concomitant examination type in the W2 PIF, other than the years of a patient's various examinations, may form another stumbling block. Where a physician requests films of a particular examination type on a patient, the file clerk may go through the pains of locating the master envelope only to find that such an examination had never been conducted.

Finally, in all of the foregoing, the presently used manual transcription of patient film retrieval data engenders human error and lack of clarity. Moreover, the original PIF location information is not immediately accessible to all physical file areas for reference.

The general aim in film location and retrieval functions may be stated as: Have the appropriate old films ready when a physician or other borrower requests them or have them ready before the arrival of corresponding new films to the file area. One way to study the adequacy of the system in satisfying the department's requirements is to determine the frequency with which requested films could not readily be found. Such a study was conducted, considering the number of films requested, the totals of those not available, and the various reasons they were not available. (The data was obtained from X-ray film request forms submitted to the W2 or B2 filing areas for a one-to-two-week period, by the attending physician or by those needing films for conferences.) At any one time, about one-fourth of the desired films were not available for one reason or another in the initial search for the patient's film folder (personnel questionnaire responses had indicated an inability to furnish films on request in this regard about 30 percent of the time), and, of this number, only approximately 15 percent could be accounted for as to their whereabouts at the time of request. However, most of the rest were somehow located (or 10 percent of those requested may have actually not been existent -- constituting routinely requested films on new admissions), since actual film loss has been rated at less than 1 percent.

A more thorough analysis was done on film requests submitted to the W3 filing area (standing clinic requests from attending physicians in the Outpatient department) where more careful records are kept of clinic film transactions. The results are shown in Table 7* and indicate that, of the sample number of films requested (489), 16 percent were not available upon request. The reasons commonly given were:

- Two percent were because the films had been either destroyed (were older than the allotted time) or had just been taken and were still in the interpretation process.
- Three percent with "not in Patient Index File" specifically indicated; i.e., there were no previous takes.
- Four percent were loaned out to personnel on other floors or clinics.
- Seven percent could not be found with no reason given as to why.

The search for "missing" films may extend to many areas within the hospital, with leads provided by the last loan-out entry, etc. There are many contributing factors leading to film displacement, and among them are (a) a failure to record transferral of films from one file area to another, (b) a failure to notify the file room when films are kept out more than the usual length of time, or when personally lent to someone else, (c) failure to take positive action when films are not returned when they are supposed to be, and (d) a failure to check off on a film request form that it has already been acted upon.

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*The numbers given represent only a portion of the films loaned from the total White filing complex. Total estimates of loans from White-2 and White-3 file areas approach 300 per day.

Table 7. Clinic Films Loaned Out -- White-3
January 20-25, 1969

Date Needed	Clinic	Number Loaned Out	Number Not Available	Reason Not Available
Saturday 1/25	Vascular	18	1	No (not found and no reason given or no record)
	Dental	3	0	
	Orthopedic	3	0	
	Total	24	1	
Friday 1/24	Orthopedic	42	6	Nii (Not in index)
			1	No
			1	Hold out (stayed in clinic)
			2	1969 (just taken)
			1	Wrong unit no.
			1	White 5AC
	Bone	8	1	**FD** (films destroyed)
	Surgical	8	1	Nii
			1	Ortho Clinic
	Cardiac	63	1	1969
			4	No on White 14
			2	FD
			7	No
			7	Cardiac clinic
			1	Pulmonary clinic
			1	White 7
	Dental	13	0	
	Total	134	38	
Thursday 1/23	Urology	3	0	
	Fracture	37	1	No
	Orthopedic	27	2	No
			1	Hold out (Ortho clinic)
			1	Fracture office
			1	White 5B
	Total	67	6	

Table 7. Clinic Films Loaned Out -- White-3, January 20-25, 1969 (Concluded)

Date Needed	Clinic	Number Loaned Out	Number Not Available	Reason Not Available
Wednesday 1/22	Tumor	5 (conf)	0	
	Hand	0	2	Nii
	Pulmonary	33	1	Nii
	Urology	6	0	
	Dental	12	0	
	Surgical	7	2	Nii
			1	FD
	Total	63	6	
Tuesday 1/21	Orthopedic	24	1	Nii
			1	White 5AC
	Fracture	53	4	No
			1	Ortho
			2	Nii
	Surgical	6	1	FD
			4	No
			1	Dr. signed out - White 2
	Dental	3	1	No
	Urology	5	0	
	Total	91	16	
Monday 1/20	Dental	2	1	Not returned
			4	No
	Surgical	9	2	FD
			1	No
	Orthopedic	22	1	No
			1	Dr. signed out
	Total	33	10	

The preceding illustrates a type of problem faced by any large organization where librarying functions occur and the information borrowers are concerned with duties other than maintaining an efficiently run library. Borrowers must be reminded that their compliance with the rules is essential to the overall efficiency and productiveness of the system, a fact especially true with regard to radiology film librarying.

Centralization of film filing functions would aid in alleviating some of the above-mentioned problems. A greater degree of centralization will be seen in White radiology after the move of their filing facilities into a new and larger area within the recently completed Gray Building. The system planned after the move into the new facilities is also indicated in Appendix C. These moves do not change the need for an overall filing system serving all of radiology, however. Although the argument can be raised that White and Baker radiology serve different segments of the patient population, the following facts remain:

- Differences between the systems prevent efficient interaction when patients destined for Baker are examined at White, and vice versa.
- Easy access to the X-ray film histories of a cross section of patients with diseases in common is hindered. This need is particularly prevalent in satisfying the teaching and research functions within MGH radiology.
- Continuation of the present division of film filing activities (i.e., separate Baker and White file system) will make difficult any future overall department reorganization along the lines of subspecialty as opposed to the present structure, which is according to the nature of the patient population.

It is evident that space constraints may continue to prevent the type of physical centralizing suggested. However, this would not prevent the formulation of a centralized computer file which would keep track of the entire patient population of MGH diagnostic radiology according to a predetermined set of patient and disease descriptors. Patient file-folder location information would be immediately accessible to all physical file areas, and the time required for search and location of patients' file folders would be reduced proportionately.

5.4 DIAGNOSTIC REPORTING

The delays encountered in the X-ray diagnostic reporting procedure have been documented both within MGH radiology (Appendix G) and within the radiology departments of other hospitals (e.g., Johns Hopkins, ref. 20 and 36). These delays can best be appreciated by considering the method used in the reporting procedure within MGH. The sequence of events is illustrated in the process sequence narratives for film filing and reporting procedures (Baker 1 and 2, White 1 and 2). The system requires that the radiologist dictate his diagnosis, using one of a number of dictaphones located in each viewing area. The tapes are retrieved periodically by a medical secretary and transcribed onto the form provided with the radiological request form. The typed copy is then returned to the radiologist who checks and approves the final copy. Corrections, if required, are made, and the report accuracy is then rechecked by the radiologist. Signed report copies are then distributed through the hospital mail. Verbal reports on stat cases can be reported by phone, but hard copy of the reports must follow.

The time required for this procedure (from the time the X-ray report is dictated to the time it is corrected and ready for dissemination) can and does vary considerably. To document the delays, the progress of RRF's originating in the White Building (W7 and 10, W-Surgical, Medical, and Fracture Clinics) and Baker (B6 and 9) were analyzed. The results are provided in Appendix G where the various aspects of the overall time delays encountered in moving a patient through the system are presented. The average time lag between initiation of the X-ray request and final report dissemination (increment 1 through 10) was found to be 1-3/4 days on White and 2-2/3 days on Baker. This time lag was in excess of 12 hours for 96 percent of Baker RRF sheets, 83 percent of W7-10, and 97 percent of W-Clinic* cases. It was found to vary from 3.7 hours to 195.7 hours on Baker, from 2.8 hours to 353.3 hours on W-Clinics, and 4.2 hours to 155.3 hours on W7-10. Furthermore, 50 percent of the RRF's took longer than 50 hours to process on Baker, and longer than 40 hours on W7-10.

On W2 the dictaphone tapes are retrieved for transcription theoretically every 45 minutes, but a delay in this part of the procedure may take anywhere from 5 minutes to 8-1/2 hours** (increment 7-8; time between report dictation and typing). Transcription requires additional time, and in many cases a number of reports will be transcribed at one time before they are returned to the responsible radiologists. Following this step, the report must be returned and approved, and delays result (increment 8-9) if the radiologist cannot be located immediately. After report approval, its dissemination is subject to the additional delays, which consumes about 4.4 hours on W2 and 3 hours for W-Clinics.*** Thus the average time required between initial report dictation and final report dissemination (increment 7-10) was 17 hours on W7-10, 9-1/2 hours in W-Clinics and 27-1/3 hours for B6-9.

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*Not including the Fracture Clinic data (42 percent of the clinic sample) since they were using an atypical patient scheduling arrangement.

**Considering transactions completed within the same day.

***Of transactions completed within the same day.

The question remains as to what can be done to accelerate the reporting process. There are a number of studies presently taking place which are concerned with the automatic transcription and transmission of diagnostic reports. These include work being done at the MGH Laboratory of Computer Sciences, Johns Hopkins Hospital, the University of Missouri (ref. 16, 20, 21, and 22). They involve the adaptation of automatic data processing techniques to the diagnostic reporting process. The major projected benefit from this approach to reporting is the elimination of delay times encountered in X-ray report transcription and delivery to terminal points.

It will not necessarily follow that the radiologist will be any less burdened with the introduction of such techniques. The solution to this problem appears to lie primarily in the training of more professional radiologists to staff already overburdened departments, not only at MGH but at most major urban hospitals throughout the country where similar problems prevail. Automated reporting does promise, however, to significantly speed up the radiological process, thereby providing significant improvement in this aspect of patient care. It may also reduce the number of nonmedical personnel required in the reporting process, allowing their time and efforts to be devoted to other aspects of departmental operation.

SECTION 6

ADP SUBSYSTEM ALTERNATIVES - FILM FILING AND SCHEDULING

6.1 APPROACH

The philosophy underlying our approach to radiology system synthesis and analysis was based upon several considerations. The first of these has to do with the methods presently used within the department. The series of "manual" procedures which are now used to move a patient through diagnostic radiology can be considered a "system". This study has concentrated upon the operation of the present system to determine where automatic data processing and advanced communication techniques can significantly aid in speeding up the process.

The basis for our system considerations has, therefore, been the block flow diagrams which illustrate the details of the diagnostic radiological process as it exists within MGH. These charts were in part derived from the process sequence flow diagrams presented in Appendix B, and were presented in Figures 3 through 10. Figures 3 through 8 illustrate the sequence of scheduling through the examination process for the five services, and Figures 9 and 10 describe the film filing and retrieval and reporting sequences.

It is recognized that changes will be occurring in the physical layout of the radiology department, i.e., film filing area and subspecialty area changes as the result of available new space in the Gray Building. The system alternatives which are proposed can be applied in the new setting as well in those areas which will see no change.

The functions of the radiological process can be categorized into patient scheduling, film librarying (filing and retrieval), the examination process, and diagnostic reporting. While these categorizations are distinct, many of the patient and examination data requirements of each are common to all. Thus, while each functional aspect of the process can be considered separately as a candidate for application of automatic data processing, the data base required suggests its use in all parts of the process. This is particularly true for scheduling, film librarying, and reporting procedures.

The significance of the above statements is further revealed in Table 8. This matrix shows the data requirements associated with the various functions involved in the total X-ray process as well as in both professional and hospital billing. Note that the data requirements are those required by each station only for the purpose of fulfilling its function in the total diagnostic X-ray process and not because the data happens to exist at that point under present procedures. Also shown are the various pieces of information which will be

Table 8. Data Requirements

Location (Function)	Patient Name	Patient Unit Number	Patient Sex	Age	Patient Location (Ward, Floor, Clinic)	Patient Mobility Category	Requested Examination Type	Requested Examination Time and Date	Requested Examination Code (Hospital and Professional Fee)	Referring (Requesting) Physician	Date of Last X-ray Examination	Patient Address	Clinical Comments - Requesting Physician	Patient Admission Date	Patient Guarantor	Date of Birth	Blue Shield Number	Medicare Number	Med-X Number	Diagnosis Upon Admission	X-ray Resources Available (time slots-examination rooms)	Examination Preparation Procedures	X-ray Examination Report	Number of Radiographs	Social Security No.	Other	Prior Reports and Films	Cost Center
Nursing Station	X	X	X		X	X	X	X		X												X	X*					
Dispatch Center	X	X			X	X		X																				
Scheduler	X	X	X		X	X	X	X													X							
Examination Station	X	X					X	X		X																		
Film File Area**	X	X			X		X	X			X																	
Viewing Station (Reporting)	X	X	X	X			X	X		X			X†														X	
Professional Billing (RA)	X	X			X		X		X			X		X	X		X	X	X				X		X			
Hospital Service Billing and Accounting	X	X			X		X		X			X		X	X		X	X	X									X
Medical Records System	C	C	C	C	C					C		C		C	C	C	C	C	C	C					C			

* Report required for requesting physician's use in patient treatment.

** Data required at the film file area reflects present standard procedures in file folder retrieval for current examination. Data required for loan-out procedures is not included here. See flow charts describing film file procedures, Figures 9 and 10.

† Clinical commentary is desirable, but the radiologist usually attempts to arrive at a conclusion independently.

available from the Medical Records Computer System which is presently being installed at the MGH. The reader will note that much of the data which is repeatedly required at the various stations is available from the Medical Records System.

Each of the areas of scheduling, film filing, and reporting have been studied in detail, and varying degrees of automated information handling have been considered as alternatives for implementation in each. These alternatives have subsequently been combined to form a series of candidate systems which are evaluated on the basis of complexity, comparative cost, and projected benefits.

While the temptation to do otherwise is great, the suggestion of radical departures from the present methods used in the radiological process with MGH has been avoided. This has been dictated by the necessity to consider the system costs involved, the space restrictions imposed by the existing physical plant, and the effect of major procedural changes on the attitudes and operating habits of hospital personnel. The most significant departure from this philosophy arises in the area of diagnostic reporting.

In the discussion which follows each of the elements of the diagnostic X-ray process is treated, with the exception of the examination process itself. Several candidate subsystem alternatives are defined and discussed for each element. Certain subsystems were selected for use in total system configurations; these and their relative merits are discussed in Appendixes H and I.

6.2 SCHEDULING

The results of the RRF time flow study (Section 4 and Appendix G) and the patient waiting time study on White-2 (Appendix E) indicate the need for improved communications and coordination of activities during the scheduling phase of the diagnostic X-ray process. The candidate systems discussed below provide these improvements with varying degrees of reliance upon modern methods of communication and information handling. The systems are best described by proceeding step by step through the scheduling process associated with each.

6.2.1 Nursing Station Phone Link

Once the attending physician on the patient's floor decides an X-ray is necessary, he indicates the name of the patient and his room number, in addition to the type of X-ray required, to the unit coordinator, floor nurse, etc. The unit coordinator calls the scheduler in the appropriate radiology service and gives the following data:

Patient name

Patient location

Patient unit number

Examination type by code number and date requested

Patient condition (three categories of mobility -- ambulatory, wheeled chair, truck)

Requesting physician

The scheduler inputs patient unit number, examination type and date requested, and the patient condition at the scheduling terminal. (Because of the nature of the input data and the need for input error correction the terminal must have alphanumeric input, display, and edit capability.) As the scheduler inputs data, it is instantly displayed to assure correctness. Upon verification by the scheduler, the data is transmitted to the computer. The computer then assigns an examination time and location (examination room) for the particular patient and notes any dietary restrictions or other preparations associated with the requested examination. The patient assignment is based upon the following:

- Rooms available and the X-ray procedures they are capable of handling
- Average times required to perform the requested examinations for patients in the three mobility categories
- Time spans within which rooms can be used (e.g., 8:00 am - 5:00 pm)

The information displayed to the scheduler is

Patient name

Patient unit number

Patient location

Examination type and code

Patient condition

Examination time, date, and room

Dietary restrictions

Requesting physician

The system has thus correlated examination type, code, and dietary restrictions; patient name and unit number; and has assigned a date, time, and examination room to the patient in question. It will also place this patient data in an active-hold computer file to be made use of in film retrieval and reporting procedures. This series of events, occurring between input and display must require no more than 5 seconds of elapsed time.

The examination time and location is then conveyed to and approved by the unit coordinator, verbally, during the course of the original telephone inquiry. Upon approval, the scheduler can have the data transmitted to the patient's floor where a hard copy is printed out for insertion into the patient's current record. At those floors where low X-ray patient volume does not justify the use of a hard-copy printout, the information is transcribed (recorded) manually by the unit coordinator.

For the purpose of dispatch notification, the computer will periodically scan the roster of scheduled patients and select those whose examinations are scheduled for that time period immediately forthcoming (e.g., the next half hour). Tear-off printouts in the dispatch area will specify:

Patient name

Patient unit number

Patient location

Examination time, date, and assigned room

The procedures following these steps correspond to those presently used in taking the patient through the examination process.

6.2.2 Nursing Station Terminal Link with Dynamic Updating

This system will provide a continually visible update of the patient's radiology schedule at the patient's origination point and at the scheduling and dispatch areas within diagnostic radiology. It is best described by outlining the required procedures for inpatient scheduling.

Inpatient Scheduling -- Data on the patient requiring the X-ray examination is input at the nursing station. This data must include the following:

Patient name

Patient unit number

Patient location

Examination type (by code number) and date requested

Patient condition (select one of three degrees of mobility)

Requesting physician

Patient data may be inputted by one of the following methods, depending upon the type of terminal available:

- CRT-Keyboard -- Patient unit number, in addition to the examination type (from the Rate and Code book) and date requested, and the patient mobility category are the only input requirements. The system would then search the computer patient index file (PIF), which comprises a major part of the data base for the diagnostic radiology system, and display that data, which now exists on the addressograph plate at the nursing station, on the CRT. The display is required for patient identity verification. Upon verification the nurse releases the data for use in the scheduling process by activating a "DATA OK" key. The minimum terminal requirements for this type of data input are:

  CRT display

  Numeric keyboard with special function keys

- Addressograph-Plate Reader or Identification Card Reader-Keyboard -- This type of patient data reader could take the form of a Touch-Tone Card Dialer phone of the type used to answer credit card inquiries from businesses, etc. The Touch Tone phone buttons would be used to insert the examination (code) and date requested, and the patient mobility category. (The Touch-Tone Card Dialer is used here as an example of the type of terminal device required. Other forms of card reader-keyboard terminals could be used.) Since patient data verification, in addition to assigned examination time and location, will be required in visual or hard-copy form, a printer would also be required in the terminal area. The purpose of the ID card reader is primarily to avoid the transcribing errors encountered in manually inputting the patient unit number.

Upon data verification and activation of a "DATA OK" function key, the computer then assigns an examination time and location to the patient based upon the following:

- Rooms available and corresponding X-ray procedure capability of each
- Time required for examinations (based upon the mobility categories)
- Time blocks within which rooms are available (e.g., 8:00 am - 5:00 pm)

The assigned time and location is then displayed or printed in hard-copy form, depending upon the terminal system used. For the CRT display method, the ward nurse can note the assigned time and determine if it is compatible with other scheduled patient activities. If it is not, she can request a reschedule via the keyboard. Upon acceptance she indicates such via a "SCHED OK" function key, after which the patient's X-ray schedule is "permanently" entered into the system. The required patient preparation data is also presented at the nursing station; it is based upon the type of examination required and the time for which it is scheduled. It can be presented in verse or code form, as follows:

0 - X-ray (no prep required)

1 - Cleansing enema at bedtime

2 - Cleansing enema in morning

3 - Light supper night before

.

.

etc.

Incorporation of dynamic updating into the inpatient scheduling procedure will allow:

- A continuing comparison of a patient's scheduled time with the actual time he will be examined. This comparison is based upon any accumulated time delay increments caused by longer-than-scheduled examination times for patients who precede the patient in question.
- A display of accumulated delay times at the nursing stations in question, allowing optional rescheduling by floor personnel.
- Notification to the dispatch area of schedule delays, allowing more efficient and timely use of dispatch personnel.

The updating function will require that the scheduling system be notified upon completion of the examination of the patient. The notification function can be performed by either dispatch or scheduling personnel in the radiology service area. It will require the use of a card identifier which would accompany the patient to the examination area. Upon completion of the X-ray examination, the card is inserted in a card reader which is dedicated for use in a schedule update mode only. The computer system receives the patient unit number, notes the real clock time, and compares it with the patient's scheduled examination time to which the appropriate examination-time increment has been added. A comparison is therefore provided of the patient's scheduled "time out" with the actual "time out" and is used to compute ± delays for patients to be examined later in the day. The accumulated delays and their effect on patients subsequently scheduled can be displayed at the nursing stations, for example, on a central television monitor, similar to those found in large airport terminals. The same type of display can be used in the dispatch area within Radiology, to regulate the activities of the dispatch personnel.

It may be that economic considerations will rule out the wide-spread use of displays at all nursing stations for the updating function. Should this be the case, an alternative method is available, where only the central scheduler(s) within Radiology are notified of accumulating delays due to prolonged patient examination times. Once a "maximum accumulated delay time" is encountered, this can be brought to the scheduler's attention by flagging the examination room number where the delay is occurring on an appropriately configured display. The scheduler can then notify the nursing stations of those patients scheduled for examinations later in the day at the X-ray facility where the delay is occurring and initiate rescheduling procedures if necessary.

Outpatient Scheduling -- Candidate outpatient scheduling procedures exhibit many of the same basic characteristics as those outlined in the discussion of inpatient scheduling methods. The differences which arise are those due to the nature of the typical outpatient:

- He is usually more mobile.
- He is not residing within the hospital.
- His need for treatment is generally not as urgent as that of the inpatient.

Because of these differences, scheduling procedures will vary somewhat from the inpatient procedures, and these variations will arise from the fact that the patient himself must act to satisfy the schedule requirements.

The required input data for outpatient scheduling from the clinic area are

Patient name
Patient unit number
Patient location (clinic area)
Examination type requested
Examination date and time requested
Patient mobility category
Responsible physician

The manner in which this data is acted upon is identical to that which is described in the inpatient scheduling alternatives, except that the patient is given the scheduled examination time, area, and preparation procedures by the receptionist or nurse who initiates the scheduling procedure in the clinic area. He is expected to act on this information accordingly by following the requested preparation procedures and appearing when and where requested. Since the patient is usually ambulatory, no dispatch notification is necessary prior to examination time.

The fact that the patient controls his own activities prior to the scheduled examination time lessens the usefulness of dynamic schedule updating and notification at the clinic terminal. This function is an aid primarily to floor (nursing) and dispatch personnel in coordinating their activities with the actual X-ray examination schedules of the patients for which they are responsible. If the daily influx of clinic patients contributes to significant queuing within the Diagnostic Radiology area, however, dynamic updating and notification of the terminal (clinic) area would aid in regulating the flow of clinic patients into Radiology.

6.3 X-RAY FILM FILE AND RETRIEVAL

System uses in aiding with the X-ray film file and control functions have been defined according to varying degrees of procedural complexity and reliance on radiology system data processing equipment. ADP and communication functions range from notification of the day's pending X-ray schedule only, to a complete film library computer patient index file (PIF) which tracks the movement of the patient's file folder both within and outside of the radiology filing system. These functions are described in the following paragraphs.

6.3.1 File Area Notification Only

The information acted upon for film file use is the patient data input to the system in the scheduling process. The system then organizes the information according to actual clock time and scheduled examination time, allowing transmittal to the filing areas of those film file requests needed most immediately. Within each computer-organized time increment, patient file requests are ordered according to the terminal digits of their unit number to facilitate film file retrieval. The ordering required will depend on how the filing area is physically laid out but will be simple to accomplish from the required software standpoint.

Data is then transmitted to the appropriate file area in White-2 or Baker-2, based on the origination point of the patient scheduling information. The data required at the file area is:

Patient name and location

Patient unit number

Examination type and code

Scheduled examination date and time

This data is printed out in the file area at 15-minute intervals, organized as described above. Each patient's data is printed on a separate tear-off section of the hard-copy output to aid in film folder retrieval and subsequent collation. In addition to being printed out, the patient data is also held in a temporary memory for final verification after the examination has been given.

Once the file clerk has the data necessary for folder retrieval, the method of manual retrieval is carried out as indicated in the file function flow chart (see Figures 9 and 10). The new films and the RRF accompanying the new films, the old films, and the printout tear-off collating aid are assembled for transfer to the veiwing area. Once the new films have been read, the radiologist (or medical secretary) indicates on the computer scheduling slip that the examination was given as listed or notes any appropriate changes (examination not given, additional examinations given, examination cancelled, etc.) on the slip. This slip can then be returned to the scheduling terminal area for later batch verification and correction where changes in the scheduled examinations require it.

6.3.2 File Area Notification with Patient Index File (PIF)

This scheme is identical to that described in 6.3.1 except for the fact that an automated patient index file has been included in the system. This file would ultimately replace the Kardex and standup files which now exist in the White-2 and Baker-2 file areas, respectively.

Prior to printing out of the scheduled patient data within the file area, the PIF would be automatically interrogated as to file area location based upon the date of the last examination. The data printed out within the central active file area would be:

Patient name
Patient unit number
Scheduled examination date and time
Examination type and code
Date of last examination
File area location based upon the date of last examination

Should the indicated file area location differ from the central active file area, this same information (except for the presently-requested examination data) would also be routed to and printed out in the appropriate indicated file area.

An example of this procedure would be the presentation of request data within the proposed active file area for the MGH Gray Building. All White in- and outpatient file requests would be presented at this point in hard-copy form, as described in 6.3.1. Upon interrogation of the PIF and indication that the file folder resides in the Gray Building sub-basement file area, the data would be immediately transmitted to the sub-basement where it would be printed out for use in retrieval and transportation by dispatcher to the active file area.

The PIF interrogation and simultaneous presentation of file folder request data has several advantages associated with it. It eliminates the now-required manual look-up of patient examination data to pinpoint the file folder location. It will allow immediate action on the part of the active-file personnel in either (1) search of the active file or (2) initiation of folder preparation connected with the presently scheduled examination. In the same sense it enables the immediate initiation of search in more remote file areas (e.g., Gray Building sub-basement). It will also allow for the more efficient use of personnel who will be transporting film folders between file areas.

6.3.3 Patient Index File and Folder Location

The system described in 6.3.2 depends solely on the date of the last examination for specifying file area location of patient's folders. This requires that tight management control be maintained over film folder librarying procedures and that folders be shifted from active to semiactive file areas in precise accordance with last-examination dates and folder rotation time period requirements (e.g., from the 6-week active file to the 6-week/5-year semi-active file area, as in the proposed White-2 filing system layout). It also means that presently used manual transcribing procedures be employed to indicate the loan-out or transfer of file folders outside of the file areas for uses other than current patient X-ray interpretations. Incorporation of a method of folder location would lighten these requirements. The use of a semi-automated "log-in, log-out" procedure would provide a rapid method of more definitely pinpointing the location of a patient's folder.

A candidate system to aid in folder location will require the establishment of central log-in points in both the Baker-2 and White-2 (active-file) areas. All requests for film loans and file area transfers of folders will be channelled through these two points. The system will incorporate a PIF to which the more detailed information on file folder location will be added. Upon the request of a clinician for the loan of certain films on a patient, the file clerk will either interrogate the patient index file to determine the folder location or initiate her search on the basis of data furnished by the requester. Upon retrieval of the folder, she would then notify the computer system of the impending loan transaction by inputting the patient unit number at an appropriately configured terminal in the file area. The system would display the basic patient data, to which would be added "DATE", "TRANSFERRED FROM (AREA)", "TRANSFERRED TO (AREA)", and the films loaned information. File area, ward or clinic areas, or outside-hospital transfers would be denoted by abbreviation or code. Logging-in procedures for returning film loans would follow an identical, but reversed, procedure.

This type of film file system is similar in many ways to one which is in pilot operation in the Radiology Department at Johns Hopkins Hospital, Baltimore, Md. (ref. 20). Although the system has demonstrated its usefulness in X-ray film librarying and control, certain practical shortcomings have been revealed in the mechanics of logging films in and out of the file areas. Primary among these is the necessity for keyboard entry by file personnel of the patient unit number in the process of querying the film library computer file associated with the system. It is evident, however, that this sort of drawback need not remain. With the recent explosion in the development of various types of terminal (I/O) hardware, it is a near certainty that an appropriate terminal for this function will become available soon or could be developed at a nominal cost.

One type of terminal device worthy of attention is the combined "Touch-Tone" dial and card dialer which is being used in conjunction with the telephone by many businesses for the communication of computer data (ref. 7). It has the following features:

- Manual input of numeric (coded) data
- Two special-function keys
- Automatic (card) entry of 14 digits of information
- Acoustic coupler (telephone send-receive)
- Low cost per terminal device

This type of terminal device can be used for the following operations in the film library control process:

- Automatic input of patient unit number
- Manual input of coded data defining the "TO" and "FROM" in the film transfer process
- Computer-generated voice confirmation of the input data

The date of transfer would be a piece of data automatically furnished by a real-time clock associated with the system.

This is only one of a class of terminals, combining diverse features, which is going through a period of rapid evolution. Magnetic-tape-identification card readers, badge readers, etc., are all being incorporated into terminal concepts which may be even more applicable in the X-ray film library and control process.

6.4 POST-EXAMINATION X-RAY TRACKING

Some X-rays are requested because the films already taken cannot be found and are needed urgently (estimates at MGH are put at about 1 percent). Also, in some cases there may be communications lapses such that there is a failure to note that the requested X-rays have indeed been taken, and hence they are redone. Thus, from the standpoint of minimizing patient and staff exposure to unnecessary radiation (reducing retakes), a method is needed to record where each X-ray film, and the report that goes with it, are until both are delivered to the requesting clinician. Hence, if the film and reports do not come back when they should, the computer system can be interrogated as to whether they have been done, and if so, their location.

For the Radiology department computer system to perform this function, there must be some small-scale terminals, one located at each step of the way traveled by an X-ray film from the time it is taken until the time it is sent to the requesting clinician. Since these terminals are only for simple data entry and inquiry, they need not be full-fledged keyboard CRT terminals -- they may, in fact, be only keyboards or readers to scan plastic cards (like credit cards) or readers to scan interpretively printed paper tape.* If they are keyboards, to minimize errors they should either provide some form of readout such as "nixie" tube or electroluminescent numeric displays. Another alternative is "accounting machine" type keyboards (see ref 12 for another medical application of these) in which the keys 0-9 are available for each digit position, and the selected keys remain depressed in each column until an "enter" key releases all of them.

Each X-ray would receive an accession number at the time it is taken which would be either written on a slip of paper or entered on a plastic card or paper tape, along with the patient's hospital accession (unit) number. (It may be acceptable to use the patient unit number alone as an X-ray identifier.) Each of the following places would have an X-ray logging station: the examination room, the developing room, the viewing room, and the file room. The X-ray would then be logged out at each station and logged in at the next one by keying in these accession numbers or else by inserting the plastic card or paper tape strip into a reader and then pressing a button to indicate "log-in" or "log-out".

Each station would also be equipped with extra control buttons to allow a simple inquiry as to the status of a given X-ray. A single decimal indicator could flash the answer according to the following scheme or a similar one:

0 - Never taken

1 - Logged in but not out at the examination room

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*Such devices are available from Interface Mechanisms, Inc., Mountlake Terrace, Washington.

2 - Logged in but not out at the developing room

3 - Logged in but not out at the viewing room

4 - Logged in but not out at the file room

5 - Loaned out

6.5 DIAGNOSTIC REPORTING

The series of events involved in generating hard copy of the diagnostic X-ray report within MGH Diagnostic Radiology consumes a considerable portion of the elapsed time required for the total X-ray process. This fact was revealed by the RRF elapsed-time study, where the time lapse between the act of dictating the X-ray interpretation by the radiologist and the act of disseminating approved typed copy of the report was determined. The average elapsed times ranged from 27 hours (Baker-2 X-ray) to approximately 9.5 hours (White-2 X-ray, clinic patients), with White-2 inpatient reports requiring an average of 17 hours. These figures do not include the time required for the report to reach its destination via the hospital mail service. It is therefore apparent that one of the goals which should be set for a reporting system is that of substantially reducing the time required to complete the reporting process. This requirement has evolved because of (1) the increasing need of the patient's physician for readily available diagnostic information to aid in treatment and (2) the need to reduce the patient's time of stay within the hospital, where beds are not only expensive but also, in many cases, scarce.

There are, however, other requirements of a reporting system which arise because of the teaching and research functions which are carried out within MGH Radiology. These include:

- Rapid retrievability of reports
- Capability for analysis of data contained both in the "fixed-format" (patient data) portion of the report as well as in the report body where the anatomy and pathology of the interpretation is presented.

The above imply an "organization" of the information contained in the body of the report in a manner which allows rapid retrieval and analysis.

During the course of this study, the work of many other investigators has been reviewed in detail (refs. 15 through 22). In almost all cases, analyzability of text and speed of report generation have been major goals, and, in many, the constraint of encroaching as little as possible on the radiologist's time and effort has been imposed. The latter constraint presents a dilemma because of the present state of the art in software techniques with regard to natural pp 6-15

text verso blank

language analysis. While it is desirable to allow the radiologist to formulate his interpretations and input them to a computer in a "free-verse" manner, the ability to analyze the resulting text for key anatomical and pathological information is only in the embryonic stages of development. The various methods which have been proposed for X-ray report generation, therefore, have virtually all required that the radiologist change his way of "doing things" to varying degrees. As his behavior is allowed to become more natural, the ability to analyze via computer what he has said diminishes. It is with this set of conflicting constraints and requirements that the different methods of diagnostic X-ray report generation were analyzed. Because of the crucial part that diagnostic reporting plays in the X-ray process, this function deserves detailed examination. The results of our examination are presented in the following section.

SECTION 7
ADP SUBSYSTEM ALTERNATIVES - DIAGNOSTIC REPORTING

7.1 GENERAL OBJECTIVES

For a computer system to be really useful in the operation of a radiology department in a teaching hospital, its presence must result in some practical operational improvement in one or more of three major areas: patient care, teaching, and research, in that order. As suggested in subsection 6.5, speed of report transmission to the requesting clinician is the primary reporting requirement in attempting to improve patient care. (We do not imply that teaching and research are not related to patient care, however.) Similarly, retrievability of reports is of prime importance in the teaching and research functions. While this section does not discuss in depth the precise mechanics of report retrieval, we do not intend that its importance be minimized. Each candidate reporting system incorporates features which allow report retrieval by well-known methods, some of which are more economical than others. In any case, a properly implemented system for computer-assisted preparation of a diagnostic X-ray reports should have a beneficial impact on all three areas of importance, thus implying both speed in generation and ease in retrieving reports.

7.1.1 Patient Care

When an X-ray procedure is requested on behalf of a patient, there are usually decisions about the care of that patient which must await the availability of the X-ray report. Hence any decrease in this "throughput" time until the report is available will lead to more rapid initiation of treatment in response to changes in the patient's condition, to a shorter average patient stay in the hospital, and perhaps even to fewer of the repeat examinations which are now sometimes done because the films and reports are "lost somewhere in the system." Also, if the system simply enables the radiologist to get his reports written and keyworded* for teaching and research purposes with less time and effort on his part, he will have that much more time to spend on other essential activities.

7.1.2 Teaching

In order to learn, a medical student, intern, or first-year resident should be able to test his own judgments against reality quickly and conveniently. One way in which he can do so is to refer to old records, X-ray films, and X-ray reports of cases similar to the one he is considering after he has come to tentative conclusions. In doing so, he will be teaching himself both efficiently and realistically and at any hour of the day or night when he has to make a judgment on a case. Some form of keywording is essential if he is to be able to locate pertinent old cases conveniently and rapidly enough that the mechanics of obtaining these records do not inhibit his attempt.

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*The word "keyword" is used throughout this discussion as a generic term, representing schemes such as indexing or coding, as well as keywording in its strictest sense, to allow for rapid retrieval of diagnostic reports.

Another teaching application of ADP is, of course, the gathering of case records for lecture material by instructors. This selection of cases can be done easily if the computer system has a large number of keyworded X-ray reports in an on-line file.

7.1.3 Research

When an interesting research question suggests itself to a radiologist, the logical chain of events is a quick retrospective study to indicate if the hypothesis is reasonably probable, followed by the formulation of a prospective study, the layout of which is influenced by the findings of the retrospective study. If every X-ray report were keyworded automatically and filed in a computer mass-storage medium, the time and effort required for a typical quick-look retrospective study might be decreased from an entire summer to a few hours. Thus, many more research hypotheses could be tested, and better-designed prospective studies would surely result.

Potentially useful results could often be obtained rather quickly, sometimes in response to a seemingly casual question such as "Which rib is the one most frequently fractured?" For more involved questions, a researcher might want the information-retrieval system to print out the data according to various patient physical or even economic characteristics -- a simple matter if the patient data from the RRF and central hospital records can be automatically appended to the X-ray report at the time that the latter is generated. For instance, in studying the question "What is the incidence of bony infarcts in sickle-cell anemia?" a researcher might want the data printout organized according to the age and sex of the patients.

7.2 SPECIFIC OBJECTIVES

The obviously worthy general objectives just stated imply more specific ones, closely related to specific computer-system tasks. Three of these will be commented on here: fast throughput time for stat X-ray reports, time-saving helps for the radiologist, and automatic keywording of all X-ray reports. Each of these has some implications for the hardware-software diagnostic reporting approaches examined in detail in subsection 7.4.

7.2.1 Fast Throughput Time for Stat X-ray Reports

Although delays of a day or more may be acceptable for some situations in which clinicians order routine X-rays, such delays unacceptably compromise medical care in emergency situations and may be a serious inconvenience when dealing with outpatients. Hence, there must be some procedure in every hospital for getting X-rays taken, analyzed in written form, and returned quickly to the requesting clinician. If the hospital system does not provide readily invoked procedures for getting stat X-rays, or even if these procedures do exist but usually require much more than an hour, it may be expected that much clinician and nurse time will be wasted trying to expedite (and perhaps even simply trying to find!) stat X-rays, and much radiologist time will be wasted fending off these nurses and clinicians. An efficient, agreeable procedure for computer-assisted generation of stat X-ray reports is therefore an important objective.

There appears to be a tradeoff between radiologist time and throughput time in that those schemes which minimize throughput time (see subsections 7.4.1, 7.4.2, and 7.4.3) generally appear to require more work by the radiologist to produce the same number of words as compared to the alternatives. Hence, there should be no requirement that the stat X-ray reporting procedure also be used for the generation of routine X-ray reports.

Any improvements which can be made in routine diagnostic reporting will, however, indirectly affect the situation for stat X-ray reports beneficially in that the percentage of reports which are requested stat can probably be reduced. If getting a routine report requires only hours instead of days (as is commonly now the case), nonlife-threatening-emergency inpatient reports will not in general need to be requested stat.

7.2.2 Time-Saving Helps for the Radiologist

Although it may well be true that many early ventures into computer-assisted radiological reporting have increased, rather than decreased, the effort required for a radiologist to generate a report, this situation is surely a "growing pains" phenomenon and not a permanent or inevitable concomitant of computer usage. (For a more optimistic long-term assessment of the impact of computers on radiological practice, see ref. 23, p. 1324.)

It is reasonable to expect that, as computer usage schemes become more highly developed as a result of user experience and modifications, and as a result of important theoretical advances in pertinent areas (ref. 33), the effort per report can be reduced below what it now is in the absence of a computer. The "ideal approach" discussed in subsection 7.3, although it has to be regarded as science fiction this year, will almost surely be a reality in a decade and in widespread use within two decades -- and it obviously imposes less burden on the radiologist than almost any other conceivable approach barring the use of telepathy. In addition, there should be a direct connection between relieving the burden on the radiologist and improving patient care, teaching, and research.

The objectives considered in subsection 7.2 should also be briefly commented on here from the viewpoint of how their realization affects the radiologist's workload. In the immediate future, the rising demand for keywording of all X-ray reports threatens to actually increase the radiologist's effort per report. Salton (ref. 26, p. 1669) warns that, within a decade, there may not be enough "experts" available or willing to manually keyword all of the documents which are to be entered in information retrieval systems, making automatic keywording a practical necessity; and that time may well arrive much sooner in radiological reporting. Hence, if a computer can relieve the radiologist of the keywording burden, this at least puts him back where he was before the advent of information-retrieval computer systems boosted the demand for keywording to what it is now. Also, although they are proposed here for other reasons, schemes for using computers to generate stat X-ray reports and keep track of the whereabouts of films and reports could, if successful, be expected to save the radiologist both time and psychic energy.

7.2.3 Automatic Keywording of All X-ray Reports

In considering applications of computers to information-retrieval problems, both within and outside of the field of medicine, it appears that most systems must at present answer requests by performing searches either based on a form of keyword or descriptor matching or else on textual analysis of the type which could in principle be used to derive keywords. Thus, if the power of such computer systems is to be put at the disposal of radiologists for the teaching and research purposes already mentioned, keywording or its equivalent is necessary, which is why many radiologists now put up with it even though it is burdensome. For the benefits of keywording to fully materialize, it must be applied to all reports, so that the information-retrieval computer system user can be assured that he has really made a complete search when he has searched the reports keyworded in the system. A specific objective for the radiological reporting schemes considered in 7.4, then, is that they produce keywording or its equivalent as an effortless or almost effortless by-product of generating the report itself.

7.3 AN IDEALIZED REPORTING SYSTEM

Contemporary science fiction abounds with descriptions of man-computer interaction on the ideal plane of partners complementing each other rather than on the mundane plane of a man using a machine as is the situation today. It is useful to consider briefly what sort of system would be ideal for the act of radiological reporting, ignoring for the moment any technical difficulties which now prevent the realization of such a system. Following that, major technical difficulties are conceded and identified, and the status of current attempts to overcome them is reviewed.

7.3.1 Operational Description

For most people, including radiologists, the easiest way to produce words is to talk. The use of dictation equipment allows a radiologist to generate a report by talking; the burden of transcribing the report, and perhaps even of editing it, is simply transferred to clerical personnel whose time is not as valuable as his. Unfortunately, the report is likely to come back to him for review and signature after a considerable delay, with some mistakes.

The ideal system, then, would allow the radiologist to sit at a console and talk in whatever way (perhaps even in whatever language) is most natural for him. The system would display his report in print, continuously, as he dictates it, on a screen which completely eliminates eye fatigue. The system would also, unobtrusively: remind him of errors of omission or commission, clean up his syntax as needed, delete "uh" and "ah" and similar nonwords, delete sentences begun but abandoned in midstream, help him recall words and phrases by serving as a thesaurus, and allow him to perform editing by verbal command. It would not impose its own ideas of syntax or its own preferred terminology on him, except to the extent that doing so was desired for administrative reasons rather than because of technical limitations.

Whenever he felt that the report was complete enough, he could sign it using a graphic input device, and the system would verify his signature (or perhaps his voice pattern) and immediately print out hard copies of the report at a number of locations for him, for the requesting physician, for medical records, and so forth. The report, keyworded, would go to the central memory bank, and would forthwith be accessible for teaching and research purposes.

Various data needed for subsidiary purposes, such as patient billing and hospital-management statistical reporting, would be extracted and transmitted to the proper memory areas for accumulation.

7.3.2 What Technological Developments are Needed

A computer system capable of performing all the tasks stated and implied above is not beyond the hardware state of the art this year. Computers, memories, graphic input devices, and remote printers of high enough speed and low enough price to make the proposal attractive all exist. Nontheless, such a system is unlikely for another decade or so because the real obstacles to attaining it are not hardware but software. "Software" here means more than the customary interpretation of "computer programs" - what are lacking are fundamental algorithms for pattern recognition powerful enough to permit unrestricted voice input, to verify signatures, and - most of all - to analyze unrestricted spoken language to the point where the computer "knows what is being said" and can edit it and keyword it as well as a human being. When such fundamental algorithms evolve, their actual realization may be either by programs for general-purpose computers or by specialized hardware, or - as is most likely - by an interactive combination of the two.

Work on the technical problems of voice input (refs. 34, 35) and computer processing of natural languages (refs. 30-33) is generally to the point now where very simple things can be done predictably, with state-of-the-art hardware, but at a cost far too high to make practical applications attractive in most cases. (One possible exception is the voice input of the numbers 0 - 9 for zip-code reading by postal employees.) Natural-language processing has already been through a period of wild optimism, followed by a period of equally wild pessimism when the original technical approaches proved to have been oversold. More balanced viewpoints are now being proposed (refs. 31, 32) and some of the theoretical problems which early work ignored or attempted to overcome by brute force are beginning to yield to advances made meanwhile in both theory (ref. 33) and practice (ref. 32).

Since each radiologist could carry a unique personal identifying key device of some kind, signature or voice authenticity verification is not an important need for the radiological reporting application. By the time that the rest of the system becomes feasible, however, economic pressure from the banking and credit card industries will probably have made low-cost signature verification by computer a reality, so the system might as well use it.

In the meantime, a worthwhile radiological reporting computer system nevertheless does appear possible according to several technical approaches. Each approach has both good and bad points. Nevertheless, several of them merit serious consideration. To choose among these approaches, Massachusetts General Hospital should consider carefully which virtues of an ideal reporting system are most important to it and which drawbacks of the various approaches are the least unacceptable. These approaches are presented in the next subsection.

7.4 TECHNOLOGICALLY FEASIBLE APPROACHES

Although the system described in 7.3 may be unattainable with the hardware-software combinations possible this year, many attractive approaches are possible, and six of these have been singled out for discussion here. They are:

- Multiple-Choice Branching (MUCHBRA)
- Reduced-Effort-Conversational-Enter-Display-Edit (RECEDE)
- Conversational-Enter-Display-Edit (CEDE)
- Dictate-Transcribe-Input-Display-Edit (DITRIDE)
- Keyworded Unscanned Free Text (KUFT)
- Unscanned Free Text (UFT)

The preceding acronyms for these approaches are used freely in the discussion which follows.

Each of these six approaches has great advantages, but also has serious flaws. Obviously, each radiologist would be best off if he could use the approach whose advantages mattered most to him and whose disadvantages mattered least to him, if that were possible. The problem is to provide a hardware-software system, or a choice of systems, which will satisfy most radiologists from a practical operational viewpoint and which will not cost more than a reasonable amount of money to develop and operate.

Each of these six approaches is presented in four parts: description, advantages, disadvantages, and discussion. The first part is intended to be an unslanted statement of how a typical realization of this approach operates or would operate. The purpose of the second and third parts is self-explanatory. The fourth part is the authors' evaluation of the worth of the approach, of its relation to the others, and of what considerations might lead one to propose it. A comprehensive evaluation of all of them at once is dererred until subsection 7.5, and recommendations until 7.6.

7.4.1 Multiple-Choice Branching (MUCHBRA)

Description -- The computer system presents the radiologist, who is seated at a CRT (or a filmstrip) display terminal, with a frame-by-frame display. Each frame gives him a question and multiple-choice answers to it. It may also give him illustrations of various organs, with their various parts numbered.

Certain recent equipment developments in the field of keyboard CRT display terminals could be used to advantage in developing alternative MUCHBRA-type techniques, in addition to those mentioned in the literature (refs. 16-21).

Computer Terminals, Inc. (Edina, Minnesota) offers multiple (up to four) ordinary raster-type television sets operating off one control unit which provides alphanumeric character generation for each. Each radiologist, using a system composed of this hardware, would have three displays facing him; one would be for video-rendered filmstrips of anatomical features; the second would display the thus-far-generated portion of his report; the third would display just the sentence he was currently working on, and hence would be a kind of "scratchpad". When he had a sentence worked out to his satisfaction on the scratchpad display, he would depress an "enter sentence" key which would transfer it to the second display to be added onto the partially completed report.

A large-screen graphics terminal capable of plotting curves could display acceptable curve-plotted anatomical diagrams (like live drawings) on one screen, the bottom part of which was used for a scratchpad area, and display the partially completed message on a second screen, which could probably be operated by the same display control unit. Terminals with suitable properties are available from Computek, Inc. (Cambridge, Massachusetts) and from Computer Displays, Inc. (Waltham, Massachusetts).

The radiologist selects true and false statements, or assigns numerical weights according to a scale, by one of the following means:

- Tactile contact (touching a wire grid). This type of system is already in use by some radiologists.
- Using a light pen or a computer-graphics "tablet".
- Using a cursor spot, controlled by a joystick, by a "mouse" (movable hand-grasped marker), or by keyboard buttons. This type of system is likely to be the best at present, considering all aspects of convenience, reliability, and cost.
- Using a numeric or alphanumeric keyboard.

The computer records all answers for the present frame, and selects the next frame partly or entirely on the basis of the answers given by the radiologist for the present frame ("branching").

A final report is compiled by the computer by composing sentences, and by selecting sentences from lists of standard sentences, according to the answers given by the radiologist. The radiologist may call for a display of standard sentences, and may select one or more of them for use in his report, by means of appropriate control keys. "Quick negatives" are merely one special class of standard sentence here. The following are some possible standard sentences for radiological reporting:

- "This is a normal study."
- "This projection does not contain sufficient information to resolve the question."
- "This study is not indicative of the diagnostic possibility for which it was obtained."
- "Further studies are suggested."
- "However, if clinically indicated, further studies may be obtained."

Other standard sentences are suggested in ref. 21, Figure 6, p. 34. This reference describes a prior application of this approach (there called "pet phrases") to radiological reporting. However, the system described there has the undesirable property that the use of certain standard sentences always implies that the report is finished and triggers the corresponding actions by the computer. Reference 8 describes the use of this approach, quite successfully, for speeding up the generation of nurses' notes and allowing limited computer analysis of them.

This final report is printed out in hard-copy form for verification and signature by the radiologist.

References 16, 18, 19, 21, and 22 describe realizations of the MUCHBRA approach.

Advantages -- The MUCHBRA approach has the following advantages:

- The radiologist needs to view the X-ray and go over his report only once ("one-pass"). The report can be made available in hard-copy form, at multiple output locations if desired, as soon as he approves it. Consequently, throughput time should be minimal.
- Manipulation of a contact, joystick, mouse, or light pen is very little manual work for the radiologist. Some of this advantage is lost if he must use keyboard cursor controls or a numeric or alphanumeric keyboard, but the amount of manual manipulation is still reasonable.
- The report is automatically rendered in computer-interpretable form as an immediate byproduct of processing; no extra processing for that purpose is required.
- The structure of the program can be made to require that the radiologist cover all points which should be covered -- hence, there can be a built-in "checklist" function.

Disadvantages -- It has the following disadvantages:

- The structured format restricts the radiologist's freedom of expression in a way which may annoy some radiologists. In fact, the imposed structure may even blind the radiologist to the peculiarities of a given case, as well as making it more work to record them than simply to omit mention of them. Moreover, in some instances none of the allowed choices may fit the peculiarities of a given X-ray at all.
- It is still quite a bit of work for the radiologist to thread his way through the available system paths for getting his thoughts realized as computer-stored text. Reports generated by MUCHBRA-type systems reported in the literature (ref. 16, 18,

19, 21, 22) are likely to be extremely brief, which is to say the least a very equivocal advantage. The labor of word selection may induce the radiologist to gloss over anomalies on otherwise negative X-rays, which is most undesirable. For example, the radiologist might select "negative report" in an X-ray taken to check for pneumonia and omit any mention of an extra (but asymptomatic) cervical rib. This rib could later cause the patient some otherwise difficult-to-diagnose distress.

- The full convenience of this approach does not appear if a standard low-cost alphanumeric CRT display terminal is used. A display with a tactile-input feature, or a joystick-controlled or mouse-controlled cursor, or a light pen does make MUCHBRA fairly convenient, but it is bound to cost considerably more than a simple alphanumeric display.

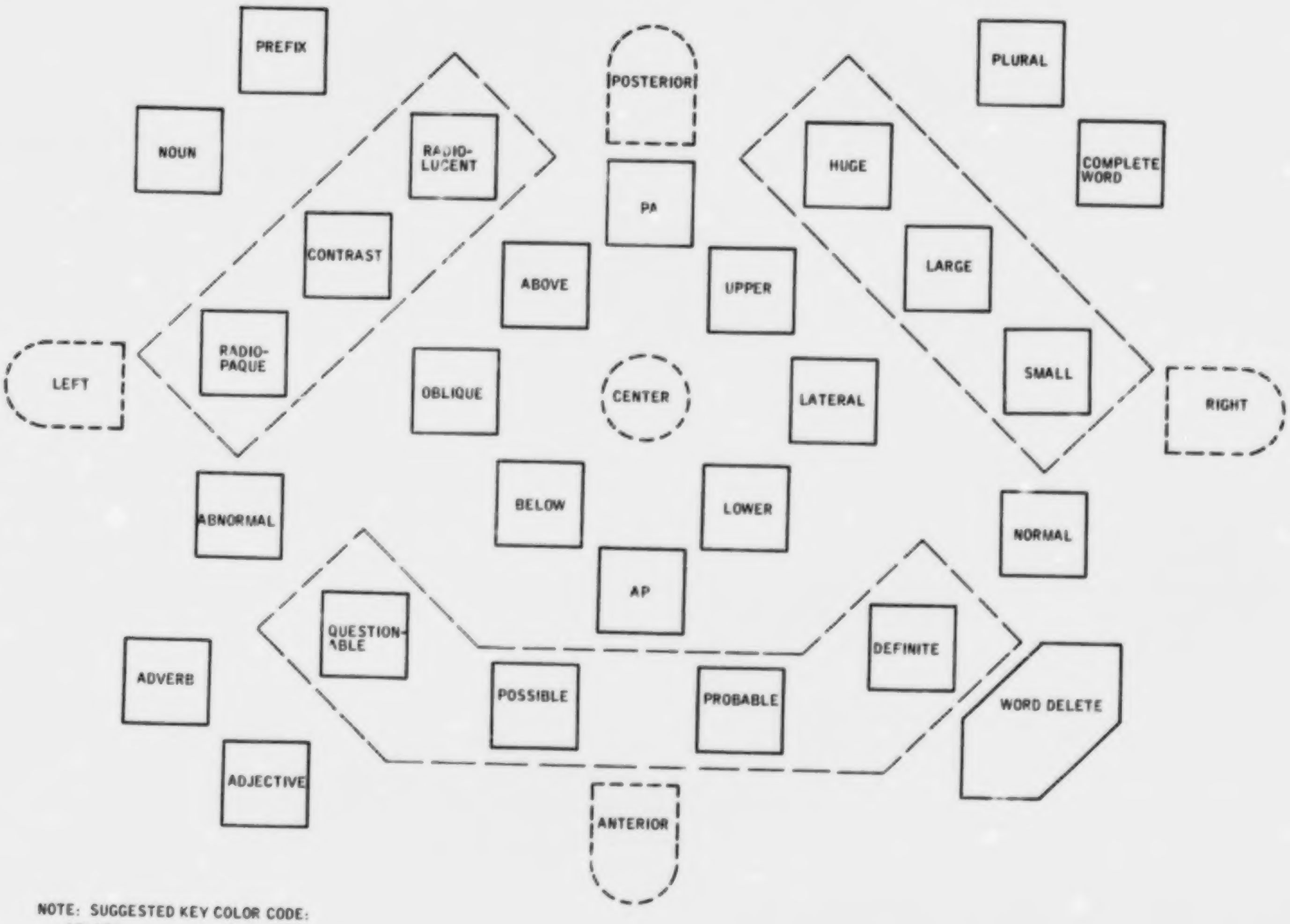
Discussion -- The MUCHBRA approach essentially entails making the radiologist operate according to the way of doing things that is most natural for a computer system, and its strengths and weaknesses are those which directly result from that philosophy. The indicated bad points are likely to be very serious for certain competent radiologists who do not naturally take to multiple-choice or "digital" type thinking. Nevertheless, this approach will almost certainly be the most efficient from a throughput-time, from a computing-time, and even from a radiologist-time viewpoint for those radiologists who find it congenial. However, developing the software to such an extent that MUCHBRA will allow the first-rate practice of radiology will undoubtedly be a lengthy task.

It is appropriate at this point to comment further on the branching logic reporting system under development at the MGH Laboratory of Computer Science. As indicated previously, this system falls into the MUCHBRA category while, at the same time, allowing additions to the report, at the disgression of the radiologist. The system incorporates techniques which allow the radiologist to enter free text by typing on an alphanumeric keyboard or to note in the brief report that a dictated report will follow. In this sense, it is a hybrid system aimed at eliminating the disadvantage encountered through the sole use of a structured, computer-generated format.

7.4.2 Reduced-Effort-Conversational-Enter-Display-Edit (RECEDE)

Description -- The radiologist, seated at an ordinary alphanumeric CRT keyboard display terminal (e.g., Datapoint 3300, Computer Terminal Corp., San Antonio, Texas) generates his report one sentence at a time. He uses a subset of ordinary English with certain syntax restrictions (see Appendix J).

He may enter words by one of several means: typing, MUCHBRA-type selection from a display, using a dense-coded keyboard such as that of Figure 11,


PREFIX
NOUN
RADIO-LUCENT
CONTRAST
RADIO-PAQUE
LEFT
POSTERIOR
PA
ABOVE
UPPER
OBLIQUE
CENTER
LATERAL
BELOW
LOWER
AP
PLURAL
COMPLETE WORD
HUGE
LARGE
SMALL
RIGHT
ABNORMAL
NORMAL
QUESTION-ABLE
POSSIBLE
PROBABLE
DEFINITE
ADVERB
ADJECTIVE
ANTERIOR
WORD DELETE
------ SHAPED BUTTONS
—— —— DIFFERENT COLOR OR SHAPE

NOTE: SUGGESTED KEY COLOR CODE:

DELETE	RED
DIRECTION	GREEN
NORMAL, ABNORMAL	BLACK
SIZE	LIGHT BLUE
OPACITY	YELLOW
DEFINITIONS	GRAY
CONTROLS (EXCEPT DELETE)	ORANGE

Figure 11. 32-Code Supplementary Radiological Dense-Coded Keyboard

or word completion, according to what is most convenient and natural. Many types of dense-coded keyboards are possible. The possible configuration of Figure 11 includes relative-position and comparative terms. A word-completion scheme, which presupposes some of the features of this keyboard, is described in Appendix K.

An end-of-sentence may be determined by a period or by a special end-of-sentence key. The computer system begins to analyze the sentence (or, perhaps, group of sentences) only when it has received an end-of-sentence. At that time it acknowledges the end-of-sentence, analyzes the syntax of the received prose, and immediately indicates to the radiologist any errors he has made (misspelled words, erroneous syntax or punctuation, etc.). The radiologist may at this time not only correct the indicated errors but also insert or delete material. The system automatically generates report headings in the proper sequence whenever a "new heading" key is pressed, in conformity with the report format (see Appendix J, Figure J1).

When the report is complete, the radiologist presses an end-of-report key. If he has not completed the entry of information under all necessary headings, his attention is then called to his omissions, and he fills in the required information. A final hard-copy version of the report, which should be error-free, is then printed out by the computer system. Since syntactic analysis was performed by the computer on a line-by-line basis, no major amount of computation of that type remains to be done at the end of the report.

We found no references in the literature discussing this approach in the form described here.

Advantages -- RECEDE has the following advantages:

- The radiologist needs to view the X-ray and go over his report only once (one-pass). The report can be made available in hard-copy form, at multiple output locations if desired, as soon as he approves it. Consequently, throughput time should be minimal.
- RECEDE provides the radiologist with full power of expression; the computer system does not present him with any subject-matter restriction or bias. Except for some syntactic constraints which he must obey (see Appendix J), he is not compelled to conform to the computer's way of doing things while preparing the report.
- Computer-generated questions can be used occasionally to remind the radiologist to cover certain essential points, in addition to the heading generation function.

Disadvantages -- It has the following disadvantages:

- While the radiologist does not have to do too much typing if he becomes proficient in the use of the display, dense-coded keyboard, and word-completion features, there is a very great premium on cleverness in learning the ropes of the system in order to enter information with minimum effort.

- The computer system's insistence on errors being corrected after each sentence may distract the radiologist's train of thought.

- Although the syntactic constraints do not inflict the same amount of computer-like thinking on the radiologist as does MUCHBRA, some radiologists may still have difficulty with them, just as some probably have difficulty even with ordinary English syntax rules.

- The computer system has more computations to perform while the radiologist is interacting with it than is the case with MUCHBRA. This objection is probably not of great economic moment, since contemporary computers are very fast.

- RECEDE requires the most elaborate terminal hardware features of any of the approaches discussed. However, the cost does not seem likely to exceed $15,000 per terminal, which may still be acceptable.

- Development of the syntactic analysis software needed for RECEDE [or for CEDE (7.4.3) or DITRIDE (7.4.4)] is a distinctly non-trivial job.

Discussion -- RECEDE represents an attempt to keep the throughput-time and other advantages of MUCHBRA, while eliminating the potentialities for insidious biasing and the incentives for leaving out useful details that don't "fit" because of a too-streamlined format. Alternatively, it can be viewed as an attempt to preserve the advantages of CEDE (7.4.3), while using several different shortcuts to drastically reduce the amount of typing required of the radiologist. Whereas the organization of the displayed material for MUCHBRA is predominantly subject-matter-oriented, RECEDE also provides the word-completion feature which is verbally oriented, and thus also offers a timesaver for those radiologists who are uncomfortable with a structured multiple-choice situation but have a high degree of verbal aptitude. In fact, if equivalent display hardware, pictures, and software are used, RECEDE can essentially reduce to MUCHBRA as used by one radiologist, and to CEDE as used by another, even though many radiologists will make efficient use of all of the options it provides. The main hazard in RECEDE would seem to be that there are many ways, of varying efficiency, for entering the same word or phrase, and that a high degree of "maze-learning" aptitude is required on the part of the radiologist if he is to achieve the maximum efficiency possible.

7.4.3 Conversational-Enter-Display-Edit (CEDE)

Description -- The radiologist, seated at an ordinary alphanumeric CRT display terminal (such as the Datapoint 3300 mentioned for use in RECEDE) types in his report one sentence at a time. He uses a subset of ordinary English with certain syntactic constraints (see Appendix J), exactly as in RECEDE.

An end-of-sentence may be determined by a period or by a special end-of-sentence key. The computer system begins to analyze the sentence (or, perhaps, group of sentences) only when it has received an end-of-sentence. At that time it acknowledges the end-of-sentence, analyzes the syntax of the received prose, and immediately indicates to the radiologist any errors he has made (misspelled words, erroneous syntax or punctuation, etc., as for RECEDE). The radiologist may at this time not only correct the indicated errors, but also insert or delete material. The system automatically generates report headings in the proper sequence whenever the "new heading" key is pressed, to conform with the format of Figure J1. In effect, the radiologist and the software interact in a manner closely resembling the way in which a programmer communicates with a conversational FORTRAN compiler.

When the report is complete, the radiologist presses an end-of-message key. If he has not completed the entry of information under all necessary headings, his attention is then called to his omissions, and he fills in the required information. A final hard-copy version of the report, which should be error-free, is then printed out by the computer system. Since computer syntactic analysis took place on a line-by-line basis, no major amount of computation of that type remains to be done at the end of the report.

We found no references describing this approach in the form described here.

Advantages -- CEDE has the following advantages:

- The radiologist needs to view the X-ray and go over his report only once (one-pass). The report can be made available in hard-copy form, at multiple output stations if desired, as soon as he approves it. Consequently, throughput time should be minimal, although CEDE is likely to require more time for those radiologists who are poor typists than would RECEDE or MUCHBRA.
- CEDE provides the radiologist with full power of expression; the computer system does not present him with any subject-matter restriction or bias or require him to practice "computer-like thinking" during the composing of his report.

- CEDE requires only a low-cost alphanumeric keyboard CRT display terminal.

- Computer-generated questions can be used every so often, in addition to the heading generation function, to remind the radiologist to cover certain essential points.

Disadvantages -- It has the following disadvantages:

- The radiologist is required to do a substantial amount of typing, which will be a burden to those radiologists who never learned the touch system or who view typing with distaste.

- The computer system's insistence on errors being corrected after each sentence may distract the radiologist's train of thought.

- Although the syntactic constraints do not inflict the same amount of computer-like thinking on the radiologist as does MUCHBRA, some radiologists may still have difficulty with them, just as some probably have difficulty even with ordinary English syntax rules.

- The computer system has more computations to perform while the radiologist is interacting with it than is the case with MUCHBRA. This objection is probably not of great economic importance since contemporary computers are very fast.

- Development of the syntactic analysis software needed for CEDE [or for RECEDE or DITRIDE (7.4.4)] is a distinctly non-trivial task.

Discussion -- This scheme is in many ways a midpoint between MUCHBRA and DITRIDE (7.4.4). It shares with MUCHBRA the properties of being interactive or "conversational", of requiring only one-pass through the material by the radiologist, and of being able to provide the radiologist as he goes along with gentle reminders to cover the essentials. It shares with DITRIDE the properties of allowing the radiologist full power of expression except for some substantial syntactic constraints, and of requiring only a relatively inexpensive type of CRT display terminal. However, it has one unique drawback in that it makes the radiologist into a typist. Nevertheless, it could in practice turn out to be very efficient for a high percentage -- even a majority -- of radiologists.

7.4.4 Dictate-Transcribe-Input-Display-Edit (DITRIDE)

Description -- The radiologist dictates his report in the usual way, using either a conventional dictating machine or a centralized dictation system such as Nyematic*, which would fit in very well here. He uses a subset of ordinary English, but there are special syntactic constraints which he must obey (see Appendix J).

A secretary transcribes the report in such a way that it can be input to a computer. The most convenient scheme would be for her to type it and for the typed copy to then be read by an optical scanner, but such scanners are fairly expensive. Alternatively she could type it on a Dura office typewriter or on a Flexowriter (either of which generates a punched tape), or on a Datel or other typewriter equipped as a directly-connected computer terminal, or on a direct-entry data-recorder (Mohawk, Honeywell Keytape, Sangamo, Potter, Data Action, Vanguard, Viatron, Sycor, Logic Corporation, Computer Machinery Corporation, Inforex, etc., any of which generates some type of magnetic tape). Perhaps the best scheme of all would be for her to use a keyboard CRT alphanumeric display, which would allow her to do some preliminary editing to correct misspelled words and punctuation errors.

The computer system reads in the report, analyzes it for syntax, checks it to see that material has been included under all of the required headings (see Figure J2, Appendix J), and compiles a computer-interpretable equivalent to it.

The required software is believed to be within the state of the art (32) if enough syntactic constraints like those of Appendix J are established.

The radiologist is notified, probably by a typed-out tear-off message at some terminal attended by a clerk-typist, that his report is ready for editing. He then goes to a CRT alphanumeric keyboard display where the computer system displays his report. Error indications for misspelled words, erroneous syntax or punctuation, etc., are displayed immediately adjacent to the error in the manner of the "compiler diagnostics" supplied by a FORTRAN or COBOL compiler. At this time, the radiologist may not only correct the indicated errors but also insert or delete material by typing at the keyboard. Whenever he does so, the computer system must again perform a syntax analysis, at least in an abbreviated way, and verify that material is still present for all required headings.

When the radiologist is done making changes in the report, he approves it by using an identification card, and a final hard-copy version is printed out which should be error-free. The computer system should, however, automatically retain the report in alphanumeric form in an on-line file memory for a day or so just in case further changes have to be made. Printout may occur simultaneously at many printing stations, some of which may be physically remote from the X-ray viewing area.

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*The Nyematic® dictation system is a sophisticated method of dictation and selective transcribing. Transcription can be accomplished at a remote location and may occur almost simultaneously with the dictation process. The system is produced by Nye Products, Inc., 2003 - 15th Avenue West, Seattle, Washington 98119.

Reference 17 describes some work which could be considered an early form of this approach, and seems based on a compatible philosophy.

Advantages -- DITRIDE has the following advantages:

- It provides the radiologist with full power of expression; the computer system does not present him with any subject-matter restriction or bias.
- The radiologist is not compelled, except for some syntactic constraints which he must obey, to practice computer-like thinking during the composing of his report.
- Voice is a natural and easy medium for composing reports, and, moreover -- again with the exception of the added syntactic constraints -- DITRIDE makes no important change in the way that radiologists now generate their reports.
- DITRIDE requires only a low-cost alphanumeric-keyboard CRT display terminal for the radiologist. Of course, it also requires some equipment for the medical secretary, which at least partially offsets that cost advantage.
- As the theory and practice of computer linguistics advances (ref. 33), DITRIDE could evolve step-by-step into the ideal approach of 7.3 -- a property shared by no other approach suggested here.

Disadvantages -- It has the following disadvantages:

- DITRIDE requires the radiologist to go over his report twice, at intervals separated in time. Since better reports may thereby result, this is by no means an unmixed drawback, but it could easily delay the preparation of stat reports unless strong administrative measures were taken to minimize the transcription delay (see 7.6).
- Although the syntactic constraints do not inflict the same amount of computer-like thinking on the radiologist as does MUCHBRA, some radiologists may still have difficulty with them, as they may with syntax rules in general.

- The compilation-like process gone through by the computer will require proportionally much more computation than the analysis of multiple-choice answers. However, the speed of even small computers is now great enough in relation to that of other systems components -- including radiologists -- that this objection is not of great economic moment.

- Development of the syntactic analysis software needed for DITRIDE (or for RECEDE or CEDE) is a distinctly non-trivial task.

Discussion -- DITRIDE essentially allows the radiologist to operate almost in the same way he traditionally has operated, with just enough changes to provide a computer-interpretable version of his report as a byproduct of generating his printed-prose copy. Although he is now compelled to edit his report more carefully than before, he does not have to go too far out of his ordinary way as a concession to the needs of the computer system. The difficulties this approach poses for the computer system are resolved by sharply constraining the radiologist's syntax and by requiring the computer to go through a compilation-like process; these measures ought not to be unduly difficult to live with.

This scheme is strong in those respects where MUCHBRA is weak and conversely.

7.4.5 Keyworded-Unscanned-Free-Text (KUFT)

Description -- The radiologist dictates his diagnosis (message) into a Nyematic dictation system. At the end of his report he indexes or keywords his impressions according to a predetermined keyword listing or code scheme. One of the several lexicons already in existence (e.g., the Johns Hopkins lexicon) could serve (1) as a computer-stored dictionary against which the keywords are compared for acceptability, and (2) as a basis for subsequent retrieval. The message is then directed to a central station, where a medical secretary is available for transcribing the report.

The medical secretary uses a CRT input terminal having an alphanumeric keyboard. The radiologist's dictated message includes the patient unit number, which is used to automatically recall the report formatting data from the active patient computer file. These data are then displayed for correlation of computer file data with that furnished by the radiologist in his verbal report. Upon confirmation by the medical secretary, the data are then temporarily held for completion of the total report.

The report plus keywords or indexing code is then "typed" (entered at the terminal) and immediately displayed on the CRT to the medical secretary, allowing a preliminary edit by her of typographical errors. Edit capability is exercised through the use of rapid cursor positioning and "delete" function keys on the display keyboard.

With the completion of the report, the secretary will activate a "Transmit for Final Edit" key to relay the report to the radiologist's viewing area. The report text and the keywords (or the report plus the English equivalent of the indexing code, should a code be selected for use) will be displayed to the radiologist via a terminal with display, alphanumeric input, and edit capability. Upon final review and approval, the radiologist inputs his identification code which is, in turn, displayed for verification. Activation of a "REPORT OK" function key will cause automatic transmission of the signed report to the following areas:

- Film filing
- Professional billing offices
- Hospital billing and accounting
- Central message-dispatch center, where remaining copies are disbursed as required

Although the total report is transmitted to the designated terminal areas, only the coded or keyworded impressions are retained for permanent computer storage with other patient data.

^ computer

Reference 15 describes one early realization of this approach.

Advantages -- KUFT has the following advantages:

- The report impressions can be stored and used in research and teaching activities as well as in future diagnoses associated with a given patient, based upon the keywording or code scheme used.
- There are no restrictions imposed on the generation of the main body of the report.
- Software requirements for KUFT are more modest than for any of the other approaches discussed up to this point but are greater than those for UFT (7.4.6).

Disadvantages -- It has the following disadvantages:

- This is a "two-pass" system, requiring that the radiologist first of all generate the report material (first pass) and then edit and approve it at a later time (second pass). The time lapse between the two passes will depend upon the queuing of reports to be dictated at the central dictation station. With no queuing, the time lapse would be in the range of minutes. Administrative measures may also be appropriate here (see 7.6).

- The system requires that the radiologist conscientiously employ the keyword or code system selected for use in categorizing his impressions. If he does so, it will take him longer to generate a report than it otherwise would, so that he has some incentive to do a less than adequate job. In this respect, KUFT has drawbacks which the first four approaches do not, since in each of these the keywording is an automatic byproduct of generating the report and does not in itself require any extra work of the radiologist. This is not meant to imply, however, that total time required for report generation would be greater than that consumed using approaches 7.4.1 through 7.4.3.

Discussion -- The KUFT method of reporting requires that the radiologist keyword or index his impressions during the reporting process. While the entire report would be dictated in a conventional manner, the additional requirement would be imposed that the "impressions" portion of the report be either keyworded, using a selected list of anatomical and pathological terms, or indexed (coded) according to one of the presently available codes (e.g., the ACR index, the FMB or KIV codes, etc. See ref. 25 for a critical comparison of these diagnostic coding systems, and ref. 24 for yet another possibility). Through the use of this method, an important portion of the diagnostic report would be available for computer storage and retrieval.

The computer is used for the following tasks:

- To retrieve formatting data for the report on the patient, from the active patient file. These formatting data are generated by the radiology satellite computer and are based on data available from the hospital-wide medical record system.
- To serve in a message handling and transmission mode.
- To store the keywords or coded impression along with the patient data in a permanent computer file which could later be used in both teaching and research activities as well as in subsequent X-ray studies of a given patient.

This system more closely approaches a "natural way of doing things" for the radiologist than those previously discussed -- even than DITRIDE -- in that there are no syntactic restraints for the body of the report. An evident departure from "naturalness" does occur, however, by imposing the requirement that the radiologist code or keyword the impressions portion of his report. Although coding is successfully used in some hospital X-ray departments, in others it is met with some degree of resistance or not used at all for various reasons. An elaborate degree of coding will not be necessary in a majority of reporting cases, especially where a "no change" or negative report describes the examination results. In these instances the additional time required for report generation is minimized. This scheme contrasts with the previously described methods in that the radiologist is less involved in a complicated interaction with a terminal and is not obliged to stay within sharply defined syntactic constraints in generating a standard diagnostic report.

7.4.6 Unscanned-Free-Text (UFT)

This reporting scheme is similar to the KUFT approach, with the major exception that keywording or coding of the diagnostic report impressions is not required. The benefits derived from the use of a computer in implementing UFT are

- To retrieve formatting data for the report on the patient from the active patient files. These formatting data are generated by the radiology satellite computer and are based on data available from the hospital-wide medical records system.
- To serve in a message handling and transmission mode only.

Because of the similarity between the report-generation procedures in both UFT and KUFT, the reader is referred to the procedural description in 7.4.5, with the reminder that the keywording of the impressions section of the report is omitted. While there are some advantages associated with this omission, obvious and crucial disadvantages also arise which are not characteristic of KUFT or of the other schemes discussed earlier.

There are many references on message-handling systems in computer-technological journals. Although we did not find references in the open literature citing use of this approach on X-ray reporting, it has been considered for application in the diagnostic radiology department of Grady Memorial Hospital in Atlanta, Georgia (ref. 36).

Advantages -- UFT has the following advantages:

- A primary advantage with UFT is the fact that the radiologist is allowed to operate (i.e., dictate his reports) in a manner most like that to which he is presently accustomed. That is, only verbal dictation and visual scan of the completed version of the report are necessary.
- The training requirements for the radiologist and medical secretary (typist) are minimal, requiring only a familiarity with the terminal devices and their operation in the input, delete and/or correct, and display modes.

- Software requirements for UFT are the least of all the approaches studied.

Disadvantages -- It has the following disadvantages:

- This system, like KUFT and DITRIDE, requires two passes in the report generation process (see KUFT disadvantages).

- The report body, impressions, qualifications, etc. would not be amenable to computer analysis by means of indexing, keywords, etc. for subsequent storage and retrieval purposes. Data compaction, allowable in the case of keyworded reports, would not be possible.

- Thus, the only information available on the patient's current examination would be the examination type, time, and date -- all of which is generated during the scheduling process.

Discussion -- This type of reporting scheme is attractive from the standpoint of simplicity, speed of report generation and transmission, and both cost and personnel training requirements in implementing the system. It allows the radiologist to operate in his traditional way and requires little training on the part of the personnel responsible for transcribing the report material. Unsurprisingly, however, it accomplishes very little towards satisfying two major requirements associated with both the teaching and research functions at MGH -- rapid report retrieval, and correlation of diagnostic reports concerned with specific pathologies, anatomical features, and patient populations. Compared to the other approaches, it makes only the most rudimentary use of the power available in contemporary computer systems and represents an almost total retreat from confrontation with the real problems.

7.5 EVALUATION OF APPROACHES

The system concept described in 7.3 obviously does about all that a radiological reporting scheme can toward helping radiologists meet the general objectives of 7.1 and the specific objectives of 7.2. The presently feasible approaches of 7.4 depart, more or less, from this concept. Careful consideration of their virtues and drawbacks, and those of other approaches not presented in this report, shows that there are four rather standard virtues being sought with greater or lesser emphasis by each approach. Likewise, there are four rather standard drawbacks, one or more of which is bound to be incurred by any non-ideal approach. Some generalizations are made here about these drawbacks, and a comparative evaluation is made of all six approaches based on their objectives, their virtues, and their drawbacks.

All six of the technical approaches of 7.4 are believed to be feasible at the present time. Since it is very difficult to balance off the cost factors of each against the operational factors, only the latter will be considered in detail. The cost factors depend principally on the amount of hardware required, on any need for new hardware development (likely to be significant only for MUCHBRA and RECEDE), and on how much development of new software is needed.

Quite clearly the least ambitious approach, UFT, would cost the least to develop, but it would accomplish the least operationally once it has been developed and put into practice. All of the other five approaches are at least moderately complex and can probably be arranged in order of increasing complexity as follows: KUFT; CEDE, MUCHBRA; DITRIDE, RECEDE; the use of semicolons and commas is intended to indicate an essential tie for second place and another for fourth place in the list. The development cost factors and computing speed requirements are not believed to provide strong cost grounds for discriminating among any of these five approaches. It must be noted, however, that cost will increase with order of complexity of the system.

The technical approaches of 7.4 each are characterized by combinations of the following virtues and drawbacks:

- Virtues
  - Minimal complexity
  - Minimal effort by the radiologist to generate a report
  - Minimum throughput time
  - Minimum syntactic ambiguity, maximum ease of computer keywording (coding)
- Drawbacks
  - Failure to accomplish keywording automatically
  - Two-pass method with consequent throughput delay
  - Excessive typing or other mechanical work required of the radiologist
  - Insidious biasing of radiologist due to excessive structuring

The relevance of these is considered at length under "Advantages" and "Disadvantages" of each of the approaches analyzed in 7.4.

It is probably true that all of the indicated factors are of approximately the same order of importance. The choice must ultimately be made by the radiologists and by the clinicians who need X-rays and X-ray reports; computer technological factors should not be decisive except where there exists an overwhelming economic factor of some sort. After all, the purpose of installing a computer system in a radiology department is for it to provide service; the computer system should be the servant, not the master.

This last observation does provide one basis for discriminating among the approaches which have been presented, as follows:

First, UFT is so unambitious considering the present state of the computer art that the question is fair, "Is it a proper expenditure of scarce research and development dollars to develop a better buggy whip?" Computer systems have been capable of providing that level of service for quite a few years. We question if Massachusetts General Hospital would really wish to give up on the whole idea of automatic keywording so easily, since its value seems unquestioned, and it may be an operational necessity within a few years (see again, ref. 26, p. 1669).

Second, MUCHBRA goes far toward making the radiologist conform to a way of doing things which is natural for a computer system -- farther than most radiologists are likely to wish. Hence, the computer system would seem to be the master rather than the servant in this approach. The only reason for imposing this type of system, then, would have to be that computer-technological limitations foreclose possibilities which are basically more attractive from the viewpoint of the clientele the system is intended to serve. In any case, the reputed failure of the system described in ref. 19 should be well understood by Massachusetts General Hospital before it invests any substantial amount of money in a large-scale operational installation of a MUCHBRA approach. Moreover, it should be borne in mind that MUCHBRA is the only approach having the drawback that it may insidiously interfere with good radiological practice. Thoughtful software design and the incorporation of hybrid features (discussed in 7.4.1) will help to alleviate this situation, however.

Third, CEDE avoids the pitfall of making the radiologist deal with the computer on its own terms, but at the price of making him do a great deal of typing -- which would surely penalize some percentage of radiologists who are inept typists. It is also a subset of RECEDE, and any radiologist who is a skilled typist and would be happy with CEDE would be happy with RECEDE also.

The three remaining approaches all have much to commend them. KUFT may be generalized somewhat into an approach where the "Impressions" part of the X-ray report is keyworded or coded in any manner, for instance by requiring the radiologist to generate it using MUCHBRA, CEDE, RECEDE, or DITRIDE, whereas the body of the report is not keyworded and is generated

verso blank

by dictation just as at present. RECEDE contains CEDE as a subset - and may almost contain MUCHBRA also; but it provides additional features of great value to radiologists who are skilled verbally. DITRIDE represents for the radiologist the smallest change, of any of the schemes which provide automatic keywording, from the way he now operates.

7.6 RECOMMENDATIONS

We feel that DITRIDE is a feasible albeit ambitious approach and would be the best one from the radiologist's point of view; but it is a two-pass approach and hence might be less than satisfactory for getting out stat X-ray reports because of the "people delay" in getting the radiologist's dictation transcribed. Assuming, nevertheless, that DITRIDE is used for all X-ray reports, as we recommend, there is at least one reasonable way to handle stat X-ray reports:

Set up the Nyematic system so that one particular tape cartridge can be selected by any radiologist for a stat report, and take administrative measures to ensure that a report dictated into this tape always gets transcribed into computer-readable form within, say, a half hour. If there were always at least one medical secretary on duty at the report typing pool, and she were always required to keep the stat tape caught up before transcribing reports, then guaranteed throughput times of this order might be realistic.

In addition it may be observed that: in the early developmental states of the radiological report generation system, it may be desirable or even necessary to limit the automatic keywording to the "Impressions" portion of the report, according to the generalized KUFT philosophy. Hopefully, this restriction could be lifted after a year or two of operation results in the radiologists gaining skill at using the system, and in the evolutionary improvement of the system in the way of making it more natural for them.

SECTION 8
RECOMMENDED TOTAL SYSTEM

8.1 RECOMMENDED SYSTEM FEATURES

The total system configuration recommended for implementation is basically the HC system described in Appendix H with the following exceptions:

- All X-ray scheduling will be done by verbal (telephone) link from the nursing station or clinic area, to a central scheduler(s) located within Radiology. While the concept of using a terminal at the orgination point (nursing station) continues to be attractive, it is felt that terminals at many such stations cannot presently be justified for use in X-ray scheduling alone. Such a terminal as that described in Subsection 6.2.3 and Appendix H should merit further consideration, however, as the scheduling requirements for other hospital services (clinical laboratory, etc.) are evolved. Until that time, we can only recommend that the nursing station X-ray scheduling requirements be kept in mind when an attempt is made to define the required characteristics of a terminal which will interact with other hospital services in addition to Radiology.

- Dynamic schedule updating at the nursing station is not included as a recommended feature at this time. Again, this deletion is based upon cost considerations of the additional ADP equipment required at the nursing station to perform this function. It is possible to incorporate a modified form of updating into the system, however, requiring only limited hardware (e.g., several badge- or card-reader type terminals) in key locations, such as the central X-ray film processing areas. These terminals would be used to note the completion of an examination. The central scheduler(s) would be notified of the accumulated time delays associated with each X-ray room via the CRT display. They could then take appropriate action when necessary, verbally notifying the ward area that rescheduling of upcoming patients was necessary. This may be an attractive alternative if hospital personnel, upon further consideration, require updating as a necessary feature in a scheduling system.

- Incorporation of the film-folder loan and transferral system described in 6.3.3 is recommended. The card reader-keyboard-voice response terminal suggested should be evaluated on a pilot basis in the MGH environment, for use in performing film-file functions.

- The diagnostic reporting scheme recommended is the DITRIDE method described in 7.4.4, utilizing, however, the structured verse and required cues only in the "Impressions" portion of the report. The total report will be transmitted to the required destination points, and will therefore be available in hard-copy form in its entirety. The patient data, examination date, area examined, procedure, and "impressions" portions of the report will be in a form which can be stored in computer memory for future retrieval and analysis. Retrieval of reports according to information in the "Impressions" section is accomplished by inputting keywords and phrases (i.e., specific subjects, subject modifier, etc.) and requesting the computer to scan all stored report "Impressions" for these words and phrases. Computer searches correlating specific patient data with these keywords and phrases could also be performed.

A review of the total system operation is presented in the following paragraphs.

8.2 RECOMMENDED SYSTEM OPERATION

8.2.1 Inpatient Scheduling

The attending physcian on the patient's floor decides an X-ray is necessary. He indicates the name of the patient and his room number, in addition to the type of X-ray required, to the unit coordinator, floor nurse, etc. The unit coordinator contacts the Radiology scheduler with the following data:

Patient name

Patient location

Patient unit number

Examination type by code number and date requested

Patient mobility category

Requesting physician

The scheduler inputs patient unit number, examination type and date requested, and mobility category, at the scheduling terminal. (The terminal must have alphanumeric input, display, and edit capability.) As the scheduler inputs data, it is instantly displayed to ensure correctness. Upon verification, the data is transmitted to the computer. The computer then assigns an examination time and location (examination room) for the particular patient and notes any dietary restrictions associated with the requested examination. The patient assignment is based on:

- Rooms available and the X-ray procedures they are capable of handling

- Average times required to perform the requested examinations for patients in the three mobility categories
- Time spans within which rooms can be used (e.g. 8:00 am - 5:00 pm)

The information displayed to the scheduler is

Patient name
Patient unit number
Patient location
Examination type and code
Patient condition
Examination time, date and room
Dietary restrictions and/or required patient preparation

The required patient preparation data presented is based on the type of examination required and the time for which it is scheduled. It can be presented in text or code form, as follows:

0 - X-ray (no prep required)
1 - Cleansing enema at bedtime
2 - Cleansing enema in morning
3 - Light supper night before
•
•
etc.

The examination time, location, and patient preparation requirements are then conveyed to and approved by the unit coordinator, verbally, during the course of the original telephone inquiry.

There is little variation in the procedures for stat X-ray requests. After contact by phone by nursing station personnel, the scheduler would select one of the emergency time slots which are held open in the day's schedule (i.e., programmed into the scheduling system) to accommodate stat requests. This is presently done on an informal basis in the manual scheduling process.

The system has thus correlated examination type, code, and dietary restrictions, patient name and unit number, and has assigned a date, time and examination room to the patient in question. It will also place this patient data in an active-hold computer file, to be made use of in film retrieval and reporting procedures.

For the purpose of dispatch notification the computer will periodically scan the roster of scheduled patients and select those whose examinations are scheduled for that time period immediately forthcoming (e.g., the next half hour). Printout of tear-offs in the dispatch area will contain:

Patient name
Patient unit number
Patient location
Examination time, date, and assigned room

8.2.2 Outpatient Scheduling

Candidate outpatient scheduling procedures exhibit many of the same basic characteristics as those outlined in the discussion of inpatient scheduling methods. The differences which arise are those due to the nature of the typical outpatient:

- He is in most cases ambulatory.
- He is not residing within the hospital.
- His need for treatment is generally not as urgent as that of the inpatient.

Because of these differences, scheduling procedures will vary somewhat from the inpatient procedures, and these variations will arise from the fact that the patient himself must act to satisfy the schedule requirements.

The required input data for outpatient scheduling from the clinic area is identical to that required for inpatient scheduling.

The manner in which the data is acted upon is also identical except that the patient is given the scheduled examination time, area, and preparation procedures by the receptionist or nurse who initiates the scheduling procedure in the clinic area. He is expected to act on this information accordingly by following the requested preparation procedures and appearing when and where requested. Since the patient is usually mobile, dispatch notification is obviously not necessary prior to examination time.

8.2.3 X-Ray Film File and Retrieval Functions

File Area Notification -- The information acted upon for film file use is the patient data which has been input to the system in the scheduling process. The system then organizes the patient schedule information according to actual clock time and scheduled examination time, allowing transmittal of those film file requests which are needed most immediately to the filing areas. Within each computer-organized time increment, patients are ordered according to the terminal digits of their unit number and the date of the last examination to facilitate film file retrieval. The ordering required will depend upon how the filing area is physically laid out but will be simple to accomplish from the required software standpoint.

Data is then then transmitted to the appropriate file area, based on the most recent entry in the patient's computer file as to the location of his file folder.

The data required at the file area is:

Patient name and location

Patient unit number

Scheduled examination date and time

Examination type and code

Date of last examination

File area location (based upon date of last examination and/or last file-folder transferral data)

It is presented to the file area at 15-minute intervals, organized as described above. Each patient's data is printed on a separate tear-off section of the hard-copy output to aid in film folder retrieval and subsequent collation. In addition to being printed out, the patient data is also held in temporary memory for final verification after the examination has been given.

Operation of this system depends upon the existence of a current computer Patient Index File (PIF). This file would include for each patient the date and type of the last examination, file-folder loan data, etc., and would be used in conjunction with other patient data necessary to the technical and administrative aspects of the diagnostic X-ray process (retrieved from the Medical Records System). The combined data from the two computer files would be used ultimately to replace the Kardex and stand-up files which now exist in the White-2 and Baker-2 file areas, respectively.

Prior to the printing out of the scheduled patient data within the file area, the PIF would automatically be interrogated as to file area location based upon the data of the last examination and/or the latest file folder transferral data which has been inputted to the system (discussed below).

Should the indicated file area location differ from the central active file area, this same information (except for the presently-requested examination data) would also be routed to and printed out in the appropriate indicated file area.

An example of this procedure would be the presentation of folder request data within the proposed active file area for the MGH Gray Building. All White in- and out-patient file requests would be presented at this point in hard-copy form, as described above. If, during the process of automatic interrogation of the PIF, there is an indication that the file folder resides in the Gray Building sub-basement file area, the data would be transmitted simultaneously to the sub-basement where it would be printed out for use in retrieval and transportation by dispatcher to the active file area.

Film Folder Loan And Transferral -- The use of a semi-automated "log-in, log-out" procedure will provide a rapid method of more definitely pinpointing the location of a patient's folder.

The logging procedures will require the establishment of central log-in points in both the Baker-2 and Gray Building (active-file) areas. All requests for film loans and file area transfers of folders will be channelled through these two points. The system will utilize the PIF to which the more detailed information on file folder location will be added. Upon the request of a clinician for the loan of certain films on a patient, the file clerk will either interrogate the patient index file to determine the folder location, or initiate her search on the basis of data furnished by the requester. Upon retrieval of the folder, she would then notify the computer system of the impending loan transaction by inputting the patient unit number at an appropriately configured terminal in the file area. The system would verify the basic patient data, to which the file clerk would add "DATE", "TRANSFERRED FROM (AREA)", "TRANSFERRED TO (AREA)", and the "films loaned" information. File area, ward or clinic areas, or outside-hospital transfers would be denoted by abbreviation or code. Logging-in procedures for returning film loans would follow an identical, but reversed, procedure.

The type of terminal recommended for use in inputting folder loan and transferral data is the card-reader-keyboard input-voice response type terminal. The reader is referred to Appendix H for a description of its use in performing these file folder librarying functions.

8.2.4 Emergency Patient Handling

The handling of emergency patients in the White-1 Emergency X-ray area will differ somewhat from both inpatient and outpatient procedures. Because of the stat nature of the X-ray request, the scheduling function is not directly applicable. Computer terminal usage is thus relegated to obtaining patient data, setting up a current computer file for the particular patient to be used in the film file and reporting activities, and notifying the film file area with a request for an immediate file folder search.

To perform these functions most efficiently a terminal will be located in the Emergency X-ray area, having alphanumeric input, display, and edit capability. Upon the arrival of a patient at the X-ray area, a medical secretary will input the patient's unit number or name. The computer will then search the radiology Patient Index File for an immediate indication of the existence and location of previous films on the patient. At the same time the establishment of a current active computer file for the patient will be initiated, involving a high-priority query of the Medical Records System file. Upon indication (display) of the presence and location of previous films, an immediate request for folder retrieval will be forwarded to the indicated file area. Once these functions are performed, the remaining portion of the X-ray process would be carried out in a manner similar to that described for inpatients.

8.2.5 Diagnostic X-Ray Reporting Functions

The reporting system which is recommended for use in the total system is the DITRIDE scheme (4.4.4), with the less stringent requirement that only the "Impressions" portion of the total report incorporate verse structuring and syntactic cues. With this method, the radiologist is allowed full power of expression in virtually all of the report. The limitations are minor, requiring only that his report be dictated according to a given format (primarily for ease in transcribing, or inputting to the computer by the Medical Secretary), and that he follow simple grammatical rules when dictating his impressions (summary of findings). The system requires virtually no additional effort on the radiologist's part for recording negative reports. Fixed patient data for use in report formatting would be retrieved from the computer file at the transcribe-input terminal. This data would be arranged in a manner appropriate for use not only by clinicians but also by professional billing and hospital service accounting.

8.3 SATISFACTION OF BUREAU OF RADIOLOGICAL HEALTH DATA REQUIREMENTS

The Bureau of Radiological Health is greatly concerned with the effects of X-radiation on the patient population of this country. It is therefore a concern of theirs that automated systems for use in the Radiology environment provide data which is useful to them in their studies. These BRH data requirements are:

- Patient characteristics
    - History number
    - Age
    - Sex
    - Race
    - Height
    - Weight

- Examination factors
    - Date of examination
    - Type of examination
    - Number of exposures
    - Technical exposure factors
    - Fluoroscopic time
- Diagnostic information -- Coded summary of X-ray findings

The system which has been recommended for implementation within MGH Diagnostic Radiology will provide the following information:

- Patient characteristics
    - Patient unit (history) number
    - Age
    - Sex
- Examination factors
    - Date of examination
    - Type of examination
- Diagnostic information -- Summary of X-ray findings

The remaining data are not presently available (i.e., not now recorded) during the diagnostic X-ray process as it currently exists at MGH, with the exception of the number of films. This latter piece of information could be input to the ADP system either by the radiologist during his report dictation (i.e., made a part of the fixed format of the report) or during the film filing process. Other patient data such as height and weight is a part of his medical history and, as such, may be accessible as a part of his medical record in the Medical Records System. At present, however, this information is not a part of the data available to the radiology system. The race of the patient is also not noted. This would have to appear as an independently generated piece of data unless MGH were to include it as a part of the background information acquired during admission. The recording of technical exposure factors, as well as fluoroscopic times, could be done by either a manual monitoring process (i.e., the technologist's noting of the times involved) or the incorporation of automatic monitoring devices in the X-ray equipment used during the examination. Since the latter method would involve either modifications of existing equipment or equipment redesign, it is not likely to be met with enthusiastic acceptance. Manual monitoring of these factors is possible, however, but it will have to be made a required step in the radiological process, e.g., by means of a department-head ruling. Whether or not the incentive can be provided to bring this about is another question entirely.

SECTION 9

STUDY RECOMMENDATIONS

This study has resulted in the definition of a total system concept, recommended for implementation within MGH Diagnostic Radiology. The system is a blend of both the "high complexity" (HC) and the "low complexity" (LC) system characteristics, resulting in a total concept which will aid in satisfying the present needs and long-range goals of the Diagnostic Radiology Department at MGH.

It is recognized that this system definition study is only the first step in a long chain of events which must occur before an MGH Radiology ADP system becomes operational. To aid in defining these events, and in placing them within a projected time frame, the ADP Radiology Implementation Plan is presented in Figure 12 for consideration by MGH hospital personnel. The figure indicates where we now stand in the program timetable. The next step must be an evaluation of the proposed system concept as a prologue to implementation of the system. Once the decision to proceed has been reached, the next steps will include a detailed specification and the selection of specific hardware forms. A positive decision must also be accompanied by the dedicated support of the department in the introduction of such a system. Without this support, the realization of the total system benefits will be made more difficult. It is therefore recommended that MGH Radiology enthusiastically proceed in executing the plan laid out in Figure 12 with the goal of an operational system by 1973.

It must be noted here that the diagnostic reporting system recommended for implementation differs in concept from that presently being investigated in the MGH Laboratory of Computer Science. While we feel that a "free-verse" method of reporting utilizing a computer must ultimately be developed, it is not our intention that work on the MGH scheme should cease in favor of the "nontactile" structured verse scheme, for it too has some definite advantages. Rather, it is recommended that the MGH method be carried through the pilot study phase, where a terminal(s) is installed on site and the system can be evaluated by radiologists in an on-line mode. Concurrently, a preliminary evaluation of the structured verse concept can be carried out without heavy reliance on computing hardware in order to assess radiologists' acceptance of the method. In this manner, the relative acceptance in the users' eyes of the two methods, as the most effective means of reporting in the interim prior to the development of free-verse computer input, can be determined.

It is further recommended that the Radiology department be formally organized in the manner suggested in Figure 1, Section 2. While this organization approximates that which in fact exists informally, the lines of authority and subdivisions within the department are not recognized by all. These lines of authority, with well defined areas of responsibility for each subdivision head,

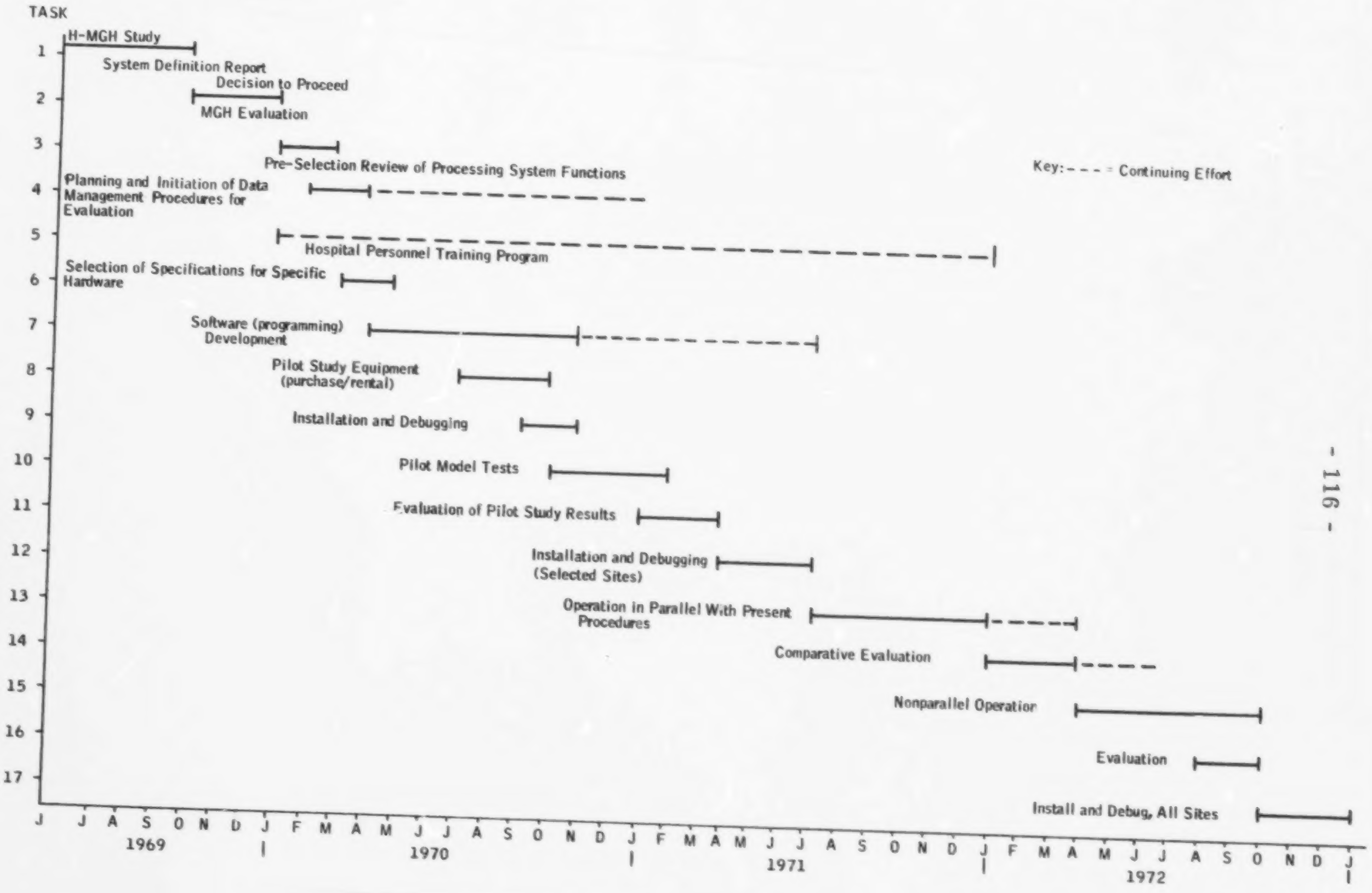

Figure 12. MGH Radiology Tentative ADP Implementation Plan

must be clearly drawn to accomplish the efficient planning, introduction, and use of an ADP system within Radiology.

It is also recommended that an additional organizational entity be introduced, namely that of Film Library and Control, with a supervisor having responsibility for all film filing and librarying activities within Radiology. The supervisor would have the overall responsibility for the Baker and Gray Building file areas as well as the Teaching Collection. He would be concerned with (1) that portion of the ADP system relating to filing; (2) continuing improvements in filing procedures and their relation to scheduling and reporting activities; (3) coordination of filing and librarying activities; (4) loan-out procedures; and (5) temporary or interim filing techniques. This definition of activity and authority is deemed necessary in view of the importance of the film-file functions in the overall diagnostic X-ray process. The further recommendation is made that uniform filing procedures be adopted both in the Baker and Gray Building file areas, i. e., that filing by color code for terminal digit and year be used in both areas.

It is finally recommended that continued on-site assessment of actual examination times for patients in the three mobility categories (ambulatory, wheeled chair, truck) be carried out. This will provide a valuable data base, not only for introducing more realism into the presently used manual scheduling procedures but also in developing the automated scheduling method outlined in the recommended system (REC) configuration.

REFERENCES *

COMPUTER USAGE IN HOSPITALS - GENERAL

1. "The Computer in Medicine," Evan C Greanias, Datamation, Vol. 11, No. 12, December 1965, pages 25-28.
2. "Joint Venture at Massachusetts General," Dr. Jordan J. Baruch and G. Octo Barnett, M.D., Datamation, Vol. 11, No. 12, December 1965, pages 29-33.
3. "Use of a Time-Shared General-Purpose File-Handling System in Hospital Research," S. I. Allen, M.D., G. O. Barnett, M.D., and P. A. Castleman, Proceedings of the IEEE, Vol. 54, No. 12, December 1966, pages 1641-1648.
4. "Computers in Patient Care," G. Octo Barnett, M.D., The New England Journal of Medicine, Vol. 279, No. 24, December 12, 1968, pages 1321-1327.
5. "A Punch-Card Laboratory Reporting System with a Cumulative Summary Format," John A. Walsh, MS, MBA, and Sidney A. Goldblatt, M.D., Journal of The American Medical Association, Vol. 207, No. 9, March 3, 1969, pages 1671-1678.
6. "The Use of Optical Scanning as a Means of Computer Input in Medicine," B. E. Spivey, M.D. and John O'Neill, Journal of The American Medical Association, Vol. 208, No. 4, April 28, 1969, pages 665-672.
7. "The Telephone as a Computer Input/Output Terminal for Medical Information," Scott I. Allen, M.D., and Michael Otten, Journal of the American Medical Association, Vol. 208, No. 4, April 28, 1969, pages 673-679.
8. "Institute's Computer Leads Many Lives," MWN staff, Medical World News, May 23, 1969, pages H14-H15.
9. "Computer-Based Hospital Information Systems," J. Peter Singer, Datamation, Vol. 15, No. 5, May 1969, pages 38-45.
10. "Computers in Medicine," Norman J. Reilly, Datamation, Vol. 15, No. 5, May 1969, pages 46-49.
11. "Information Handling Costs in Hospitals," Geoffrey G. Jackson, Datamation, Vol. 15, No. 5, May 1969, pages 56-59.

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*The order of these references within each major heading is chronological.

12. "Diversified Numeric Applications On-Line Clinical Laboratory System," Neil I. Fishman and Robert L. Strom, M.D., Minnesota Medicine, Vol. 52, No. 5, May 1969, pages 853-861.

13. "The Little Computer that Could," Harry T. Paxton, Hospital Physician, June 1969, pages 60-67.

14. "Centralized Health Data Systems: Privacy, Confidentiality and Other Legal Considerations," William J. Curran, J.D., S.M. Hyg., Barbara Stearns, J.D., and Honora Kaplan, M.P.A., The New England Journal of Medicine, Vol. 281, No. 5, July 31, 1969, pages 241-248. (See also a related editorial, "On Confidentiality and Data Banks," pages 269-270 of the same issue, by Lendon Snedeker, M.D.)

RADIOLOGICAL REPORTING APPLICATIONS

15. "Computer Processing of Neuroradiological Reports," Julius Korein, M.D., Irvin I. Kricheff, M.D., Norman E. Chase, M.D., and Clark T. Randt, M.D., Radiology, Vol. 84, No. 2, February 1965, pages 197-202.

16. "RADIATE: A New Concept for Computer Coding, Transmitting, Storing, and Retrieving Radiological Data," Arch W. Templeton, M.D., Gwilym S. Lodwick, M.D., Arch H. Turner Jr., B.A., Radiology, Vol. 85, No. 5, November 1965, pages 811-817.

17. "Computer Autocoding, Selecting and Correlating of Radiologic Diagnostic Cases, A Preliminary Report," Howard J. Barnhard, M.D., and John M. Long, Ed. D., American Journal of Roentgenology, Vol. 96, No. 4, April 1966, pages 854-863.

18. "Automatic Typing and Translating of Radiological Reports," Inger Brolin, M.D., The Proceedings of the Conference on The Use of Computers in Radiology, Chicago, October 20-23, 1966 (published at the University of Missouri, 1968), pages D-3 through D-17.

19. "System for Recording Neuroradiologic Diagnoses in a Computer," Gordon T. Uber, M.S., and Hillier L. Baker, M.D., Radiology, Vol. 91, No. 2, August 1968, pages 241-247.

20. "Application of Computer Techniques to Selected Diagnostic Radiology Operations", Stanley I. Margulies, M.D., and Joseph N. Gitlin, M.P.H. Presented at the 12 November 1968 American Public Health Ass'n Meeting.

21. "RADIATE: Updated and Redesigned for Multiple CRT Terminals," Arch W. Templeton, M.D., Peter L. Reichertz, M.D., Eleonore Paquet, M.D., J. L. Lehr, M.D., Gwilym S. Lodwick, M.D., and Francis I. Scott, B.S., Radiology, Vol. 92, No. 1, January 1969, pages 30-36.

22. "An On-Line Computer Facility for Systematized Input of Radiologic Reports," Henry P. Pendergrass, M.D., Robert A. Greenes, M.D., G. Octo Barnett, M.D., James W. Poitras, S.B., A. Neil Pappalardo, S.B., and Curtis W. Marble, S.B., Radiology, Vol. 92, No. 4, March 1969, pages 709-713.

23. "Radiology - A Case Study in Technology and Manpower," John H. Knowles, M.D., The New England Journal of Medicine; Part 1, Vol. 280, No. 23, June 5, 1969, pages 1271-1278; and Part II, Vol. 280, No. 24, June 12, 1969, pages 1323-1329.

RADIOLOGICAL DIAGNOSTIC TAXONOMIES

24. "An Improves Radiological Classification of Diseases," Morris Simon, M.D., British Journal of Radiology, February 1965.

25. "Comparative Study of Roentgen Diagnostic Classifications," Erkki Koivisto, Supplementum 285, Acta Radiologica (Stockholm 2, Sweden), 1969.

COMPUTER SYSTEMS - GENERAL

26. "Information Dissemination and Automatic Information Systems," Gerard Salton, Proceedings of the IEEE, Vol. 54, No. 12, December 1966, pages 1663-1678.

27. "Low-Cost Remote CRT Terminals," D. J. Theis and L. C. Hobbs, Datamation, Vol. 14, No. 6, June 1968, pages 22-29.

28. "Software for Terminal-Oriented Systems," Werner L. Frank, Datamation, Vol. 14, No. 6, June 1968, pages 30-34.

29. "Elements of Data Management Systems," George G. Dodd, Computing Surveys (An Association for Computing Machinery publication), Vol. 1, No. 2, June 1969, pages 117-133.

COMPUTATIONAL LINGUISTICS AND EDITING

30. "Computer-Assisted Writing," Robert A. Magnuson, Datamation, Vol. 12, No. 6, June 1966, pages 49-59.

31. "Natural Language Processing," R. F. Simmons, Datamation, Vol. 12, No. 6, June 1966, pages 61-72.

32. "Machine Translation - Fact or Fancy?" Paul L. Garvin, Datamation, Vol. 13, No. 4, April 1967, pages 29-31.

33. "Information in Natural Languages," Paul A. Shapiro, Irwin D. J. Bross, Ph.D., Roger L. Priore, ScD., Barbara B. Anderson, Journal of The American Medical Association, Vol. 207, No. 11, March 17, 1969, pages 2080-2084.

VOICE INPUT SYSTEMS

34. "Voice Controlled Teaching Unit Would Give Student Initiative," Walter G. Peck, Electronic News, Computer Trends liftout section, May 12, 1969, page 12.

35. "Computer Buys and Sells at Stockholders's Order," ET staff, Electro-Technology, Vol. 84, No. 1, July 1969, page 17.

OTHER

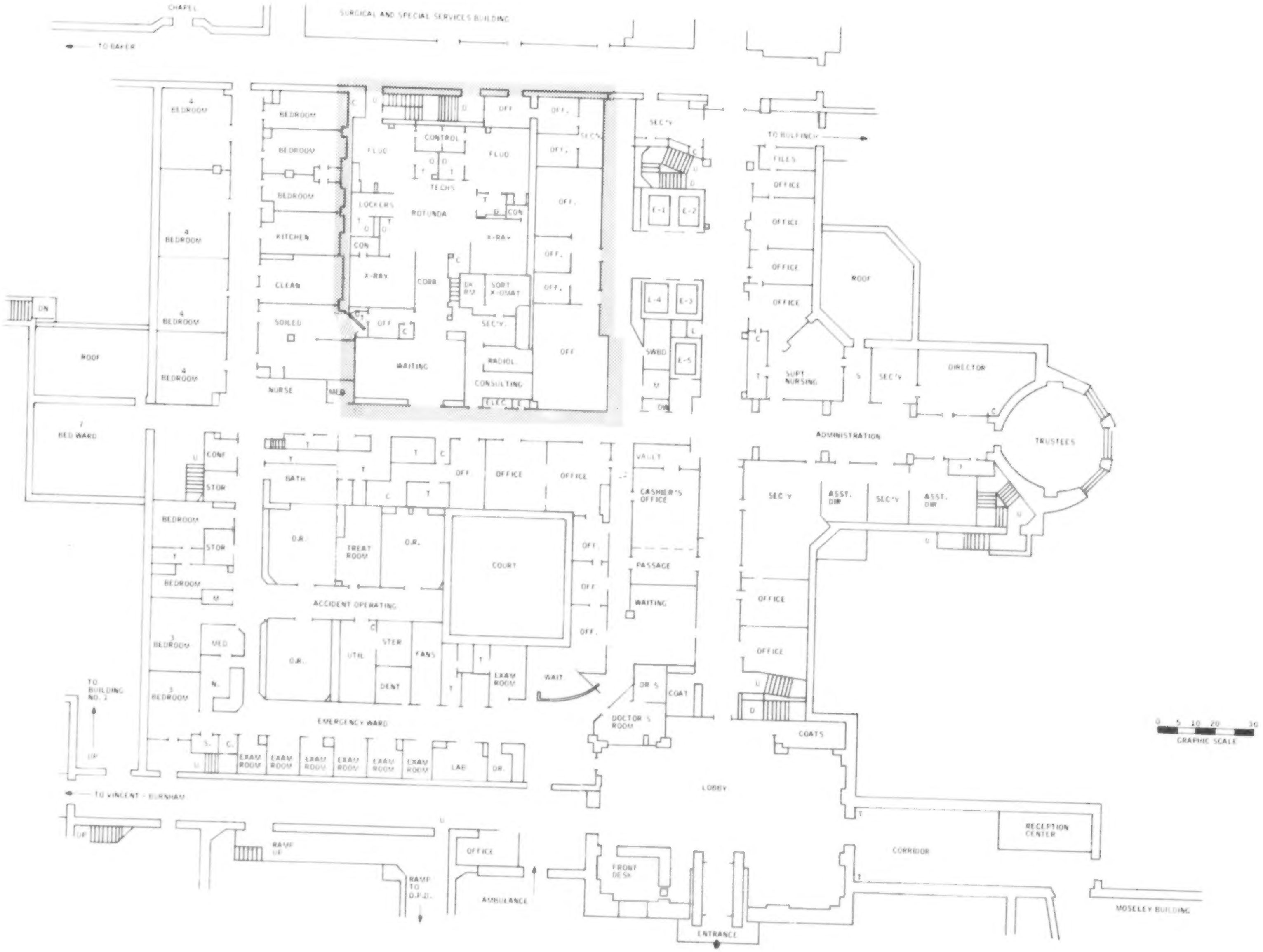
36. Personal communications, J. N. Gitlin and F. G. Rueter, Bureau of Radiological Health, to H. W. TenBroek.

APPENDIX A
RADIOLOGY SUBAREA FLOOR PLANS

APPENDIX A
RADIOLOGY SUBAREA FLOOR PLANS

The physical layout of MGH Radiology is shown in Figures A1 through A7.

The primary subdivisional areas are White-1 and -2, Baker-1 and -2, and Phillips House. Film filing activities are carried out on White-3 and White-14.


CHAPEL
SURGICAL AND SPECIAL SERVICES BUILDING
TO BAKER
4 BEDROOM
4 BEDROOM
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4 BEDROOM
BEDROOM
BEDROOM
BEDROOM
KITCHEN
CLEAN
SOILED
NURSE
MED
DN
ROOF
7 BED WARD
FLUO
CONTROL
FLUO
TECHS
LOCKERS
ROTUNDA
CON
CON
X-RAY
X-RAY
CORR
DK RM
SORT X-OMAT
OFF
SEC'Y.
WAITING
RADIOL.
CONSULTING
ELEC
OFF
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SEC'Y.
OFF.
OFF.
OFF.
OFF.
OFF
SEC'Y
E-1
E-2
E-4
E-3
E-5
SWBD
M
DW
TO BULFINCH
FILES
OFFICE
OFFICE
OFFICE
OFFICE
ROOF
SUPT. NURSING
SEC'Y
DIRECTOR
TRUSTEES
ADMINISTRATION
SEC'Y
ASST. DIR
SEC'Y
ASST. DIR
OFFICE
OFFICE
COATS
CONF
STOR
BEDROOM
STOR
BEDROOM
M
3 BEDROOM
MED
N.
3 BEDROOM
BATH
OFF
OFFICE
OFFICE
VAULT
CASHIER'S OFFICE
PASSAGE
WAITING
O.R.
TREAT ROOM
O.R.
COURT
OFF
OFF
OFF.
ACCIDENT OPERATING
O.R.
UTIL
STER
FANS
DENT
EXAM ROOM
WAIT
DR. S
COAT
DOCTOR'S ROOM
EMERGENCY WARD
EXAM ROOM
EXAM ROOM
EXAM ROOM
EXAM ROOM
EXAM ROOM
EXAM ROOM
LAB
DR.
TO BUILDING NO. 2
UP
TO VINCENT - BURNHAM
UP
RAMP UP
RAMP TO O.P.D.
OFFICE
AMBULANCE
FRONT DESK
ENTRANCE
LOBBY
CORRIDOR
RECEPTION CENTER
MOSELEY BUILDING
0 5 10 20 30
GRAPHIC SCALE

Figure A1. Diagnostic Radiology - White Memorial Building, First Floor

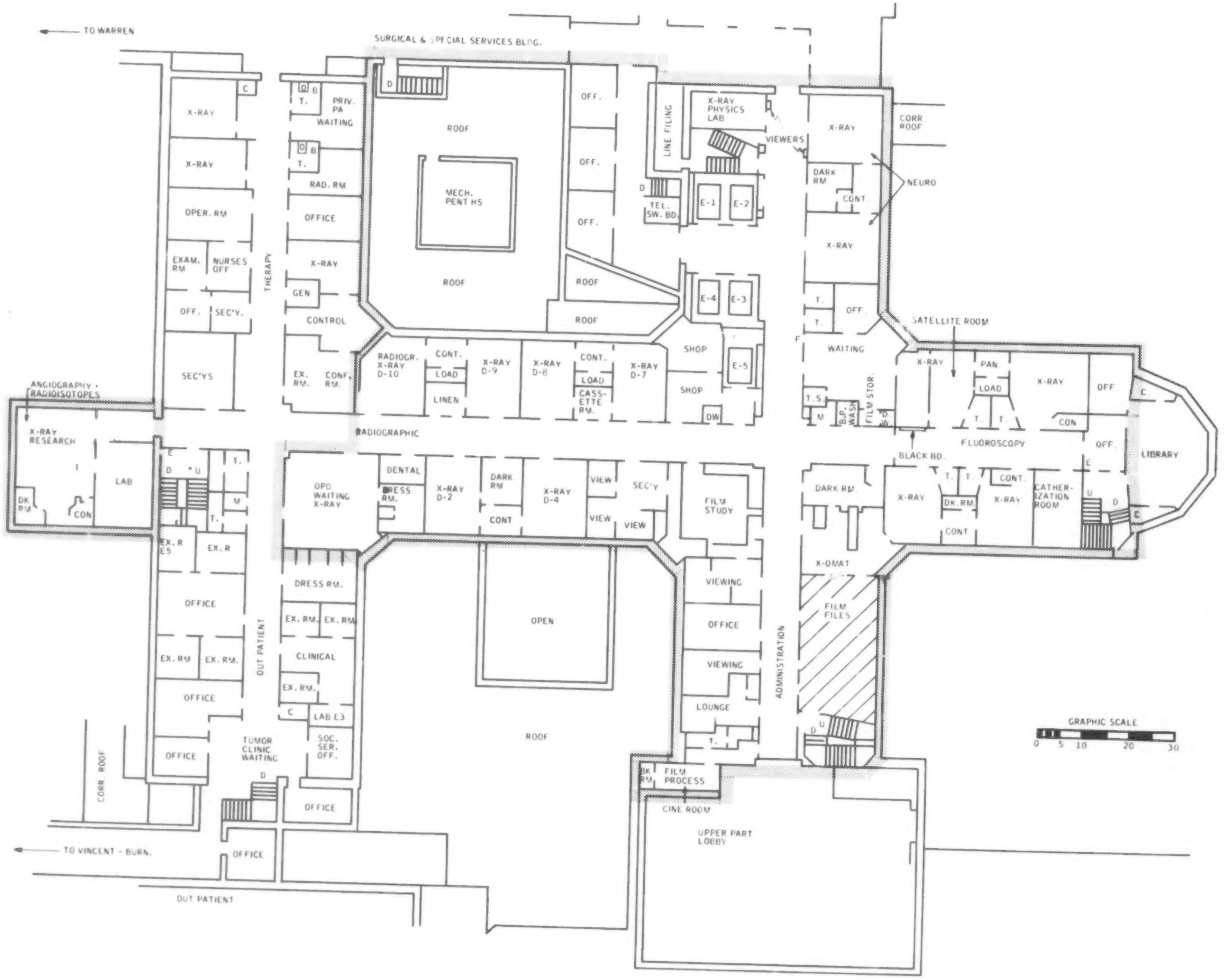
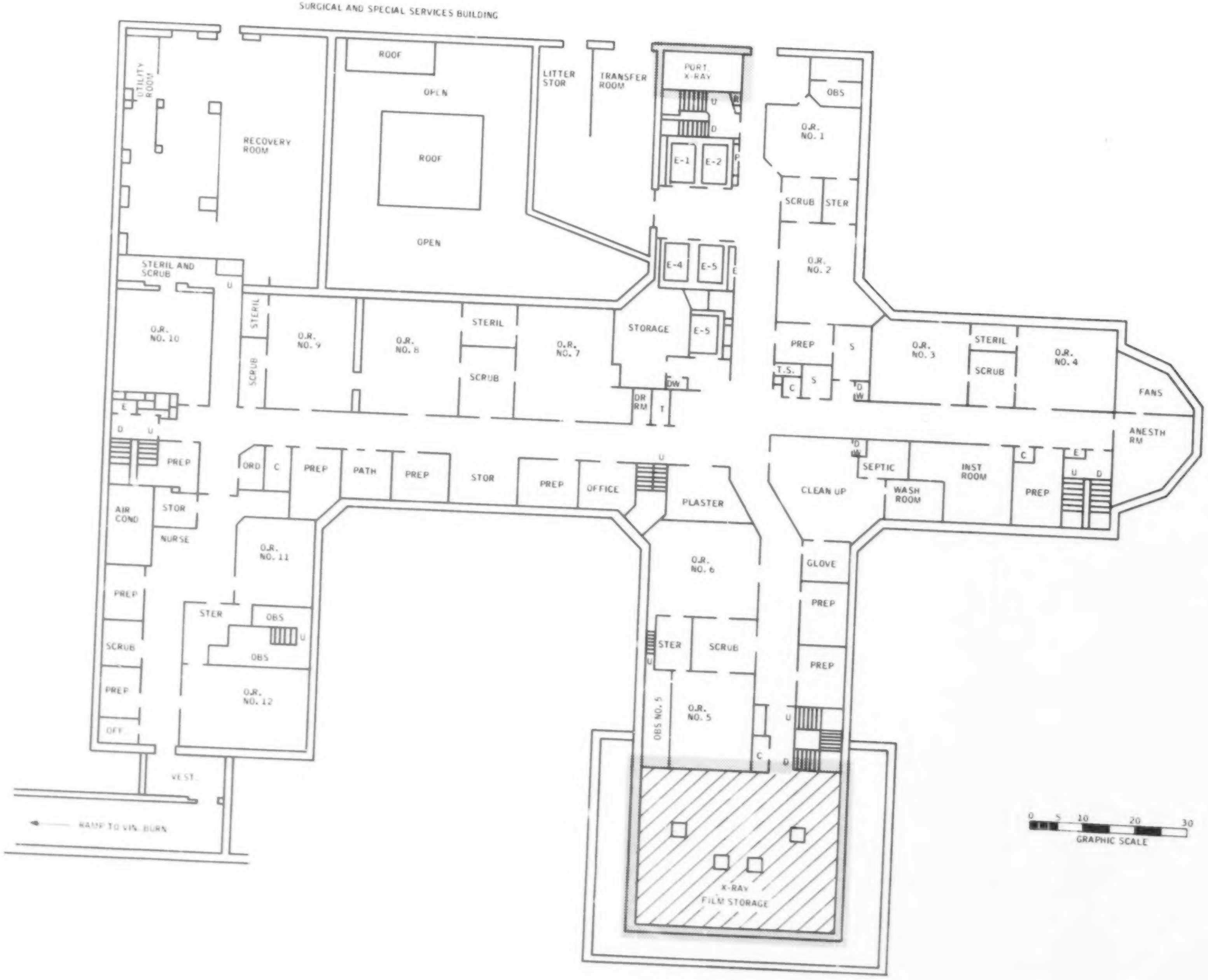

TO WARREN
SURGICAL & SPECIAL SERVICES BLDG.
X-RAY
X-RAY
OPER. RM
EXAM. RM
NURSES OFF
OFF.
SEC'Y.
SEC'YS
THERAPY
PRIV. PA WAITING
RAD. RM
OFFICE
X-RAY
GEN
CONTROL
EX. RM.
CONF. RM.
ROOF
MECH. PENT HS
ROOF
OFF.
OFF.
OFF.
ROOF
ROOF
LINE FILING
X-RAY PHYSICS LAB
TEL. SW. BD.
E-1
E-2
E-3
E-4
E-5
VIEWERS
X-RAY
DARK RM
CONT
X-RAY
NEURO
CORR ROOF
OFF
WAITING
SATELLITE ROOM
RADIOGR. X-RAY D-10
CONT.
LOAD
LINEN
X-RAY D-9
X-RAY D-8
CONT.
LOAD
CASS-ETTE RM.
X-RAY D-7
SHOP
SHOP
DW
FILM STOR.
B.P. WASH
T.S.
X-RAY
PAN
LOAD
X-RAY
OFF
CON
OFF.
LIBRARY
FLUOROSCOPY
BLACK BD.
ANGIOGRAPHY - RADIOISOTOPES
X-RAY RESEARCH
LAB
DK RM
CON
RADIOGRAPHIC
OPD WAITING X-RAY
DENTAL
DRESS RM.
X-RAY D-2
DARK RM
CONT
X-RAY D-4
VIEW
VIEW
VIEW
SEC'Y
FILM STUDY
DARK RM.
X-RAY
DK.RM.
CONT
X-RAY
CONT.
CATHER-IZATION ROOM
X-OMAT
FILM FILES
EX. R ES
EX. R
OFFICE
EX. RM
EX. RM.
OFFICE
OFFICE
OUT PATIENT
DRESS RM.
EX. RM.
EX. RM
CLINICAL
EX. RM.
LAB E3
SOC. SER. OFF.
TUMOR CLINIC WAITING
OFFICE
OFFICE
OPEN
ROOF
VIEWING
OFFICE
VIEWING
LOUNGE
ADMINISTRATION
DK RM
FILM PROCESS
CINE ROOM
UPPER PART LOBBY
GRAPHIC SCALE
0 5 10 20 30
CORR. ROOF
TO VINCENT - BURN.
OUT PATIENT

Figure A2. Diagnostic Radiology - White Memorial Building, Second Floor


SURGICAL AND SPECIAL SERVICES BUILDING
UTILITY ROOM
RECOVERY ROOM
ROOF
OPEN
ROOF
OPEN
LITTER STOR
TRANSFER ROOM
PORT. X-RAY
OBS
O.R. NO. 1
E-1
E-2
SCRUB
STER
O.R. NO. 2
E-4
E-5
E-5
STERIL AND SCRUB
STERIL
SCRUB
O.R. NO. 10
O.R. NO. 9
O.R. NO. 8
STERIL
SCRUB
O.R. NO. 7
STORAGE
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DR RM
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T.S.
C
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DW
O.R. NO. 3
STERIL
SCRUB
O.R. NO. 4
FANS
ANESTH RM
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D
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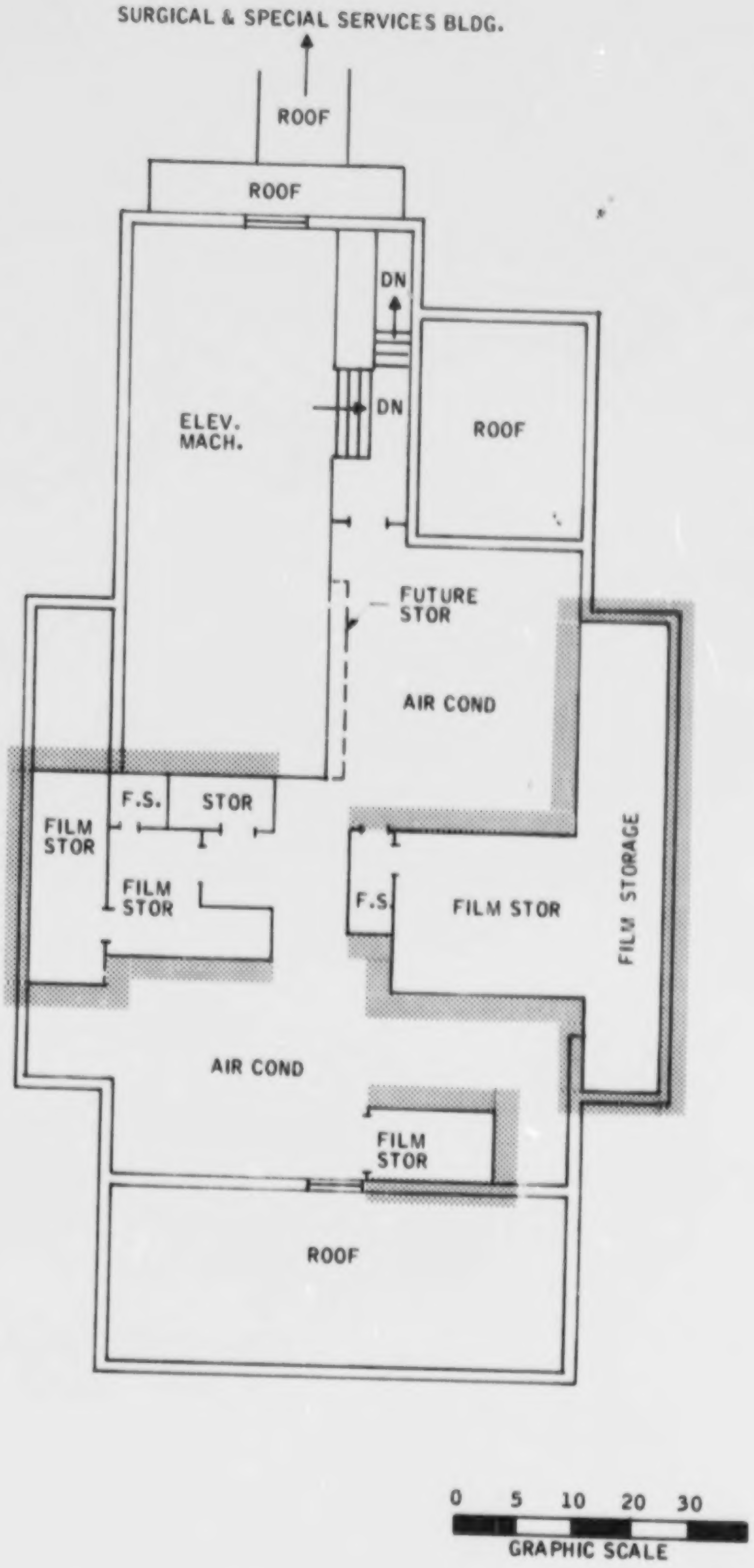
PREP
ORD
C
PREP
PATH
PREP
STOR
PREP
OFFICE
PLASTER
CLEAN UP
SEPTIC
WASH ROOM
INST ROOM
C
PREP
AIR COND
STOR
NURSE
O.R. NO. 11
STER
OBS
OBS
O.R. NO. 12
PREP
SCRUB
PREP
OFF
VEST.
RAMP TO VIN. BURN
O.R. NO. 6
STER
SCRUB
OBS NO. 5
O.R. NO. 5
GLOVE
PREP
PREP
X-RAY FILM STORAGE
0 5 10 20 30
GRAPHIC SCALE

Figure A3. Diagnostic Radiology - White Memorial Building, Third Floor


SURGICAL & SPECIAL SERVICES BLDG.
ROOF
ROOF
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ELEV. MACH.
ROOF
FUTURE STOR
AIR COND
F.S.
STOR
FILM STOR
FILM STOR
F.S.
FILM STOR
FILM STORAGE
AIR COND
FILM STOR
ROOF
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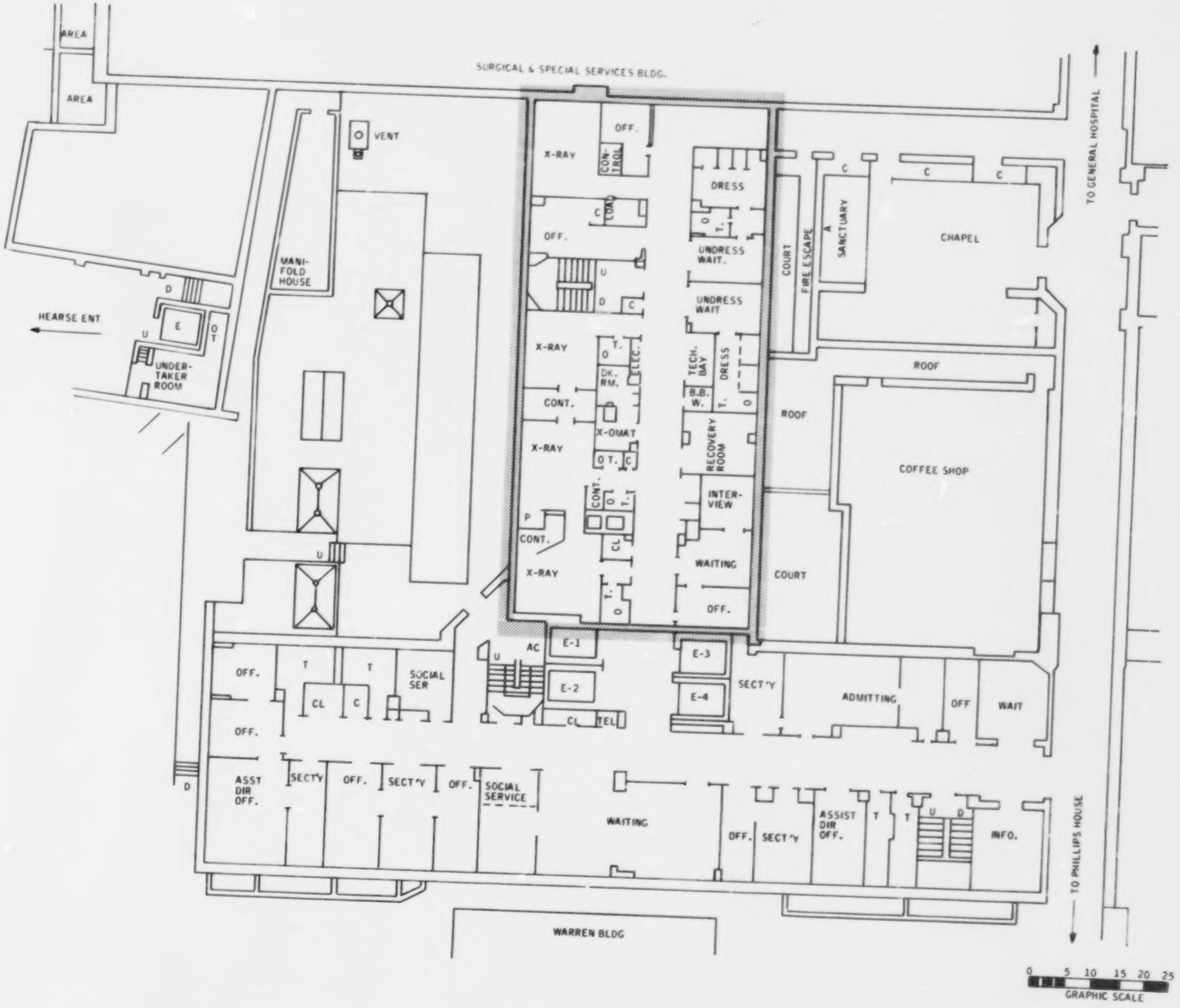
GRAPHIC SCALE

Figure A4. Radiology Film Storage - White Memorial Building, Fourteenth Floor


SURGICAL & SPECIAL SERVICES BLDG.
TO GENERAL HOSPITAL
TO PHILLIPS HOUSE
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MANI-FOLD HOUSE
HEARSE ENT
UNDER-TAKER ROOM
E
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CON-TROL
OFF.
OFF.
X-RAY
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X-RAY
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X-RAY
DK. RM.
ELEC.
X-OMAT
CL
DRESS
UNDRESS WAIT.
UNDRESS WAIT
TECH. BAY
DRESS
B.B. W.
RECOVERY ROOM
INTER-VIEW
WAITING
OFF.
COURT
FIRE ESCAPE
SANCTUARY
CHAPEL
ROOF
ROOF
COFFEE SHOP
COURT
E-1
E-2
E-3
E-4
AC
TEL
SECT'Y
ADMITTING
OFF
WAIT
OFF.
OFF.
SOCIAL SER
ASST DIR OFF.
SECT'Y
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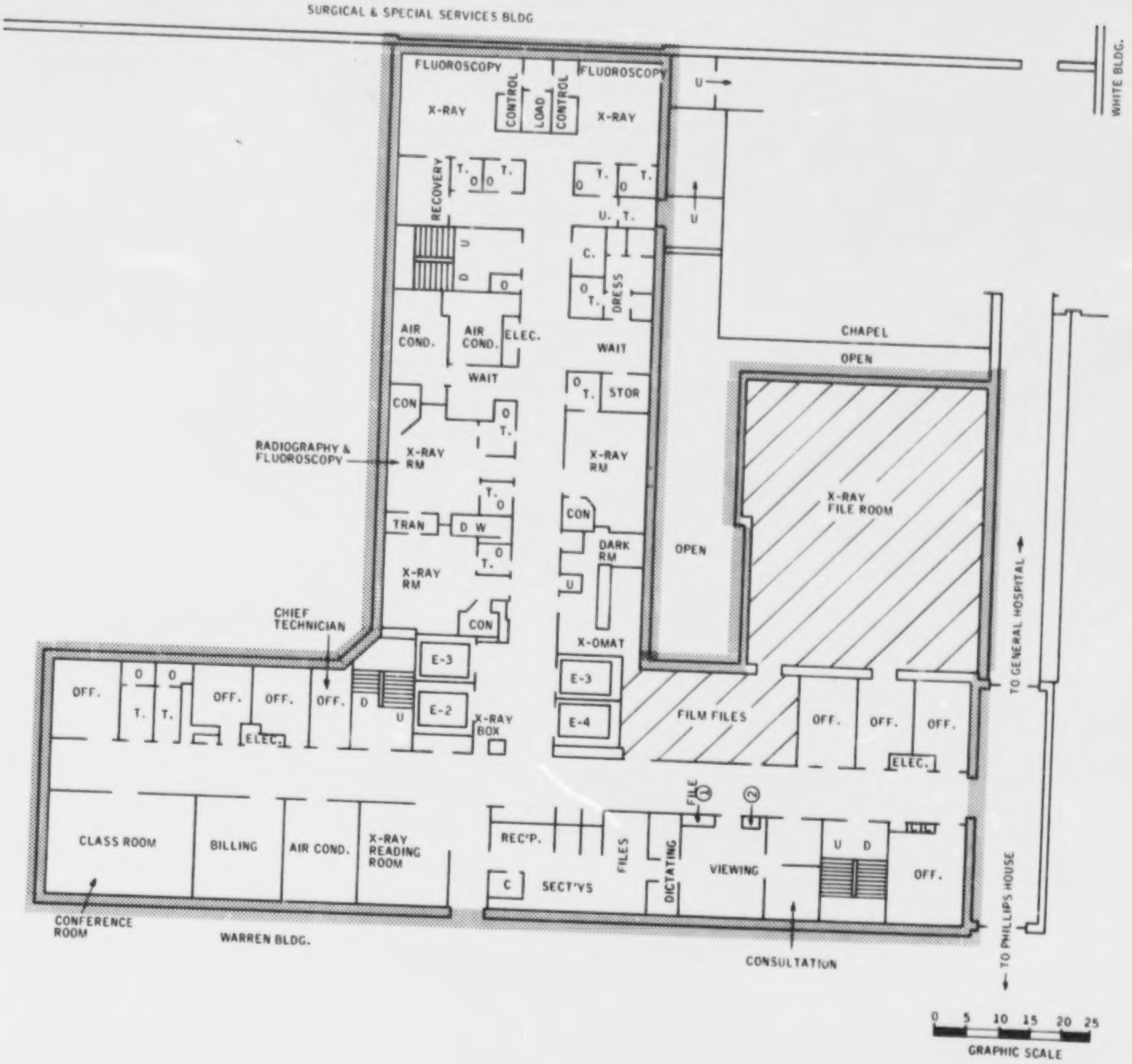
SECT'Y
OFF.
SOCIAL SERVICE
WAITING
OFF.
SECT'Y
ASSIST DIR OFF.
INFO.
WARREN BLDG
0 5 10 15 20 25
GRAPHIC SCALE

Figure A5. Diagnostic Radiology - Baker Memorial Building, First Floor


SURGICAL & SPECIAL SERVICES BLDG
WHITE BLDG.
FLUOROSCOPY
FLUOROSCOPY
X-RAY
CONTROL
LOAD
CONTROL
X-RAY
U
RECOVERY
T.
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T.
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DRESS
AIR COND.
AIR COND.
ELEC.
WAIT
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CHAPEL
OPEN
CON
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T.
STOR
RADIOGRAPHY & FLUOROSCOPY
X-RAY RM
X-RAY RM
X-RAY FILE ROOM
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TRAN
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CON
DARK RM
OPEN
O
T.
X-RAY RM
U
CHIEF TECHNICIAN
CON
X-OMAT
E-3
E-3
E-2
E-4
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T.
T.
OFF.
OFF.
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D
U
ELEC.
X-RAY BOX
FILM FILES
OFF.
OFF.
OFF.
ELEC.
TO GENERAL HOSPITAL
FILE
①
②
CLASS ROOM
BILLING
AIR COND.
X-RAY READING ROOM
REC'P.
FILES
DICTATING
VIEWING
U
D
OFF.
C
SECT'YS
CONFERENCE ROOM
WARREN BLDG.
CONSULTATION
TO PHILLIPS HOUSE
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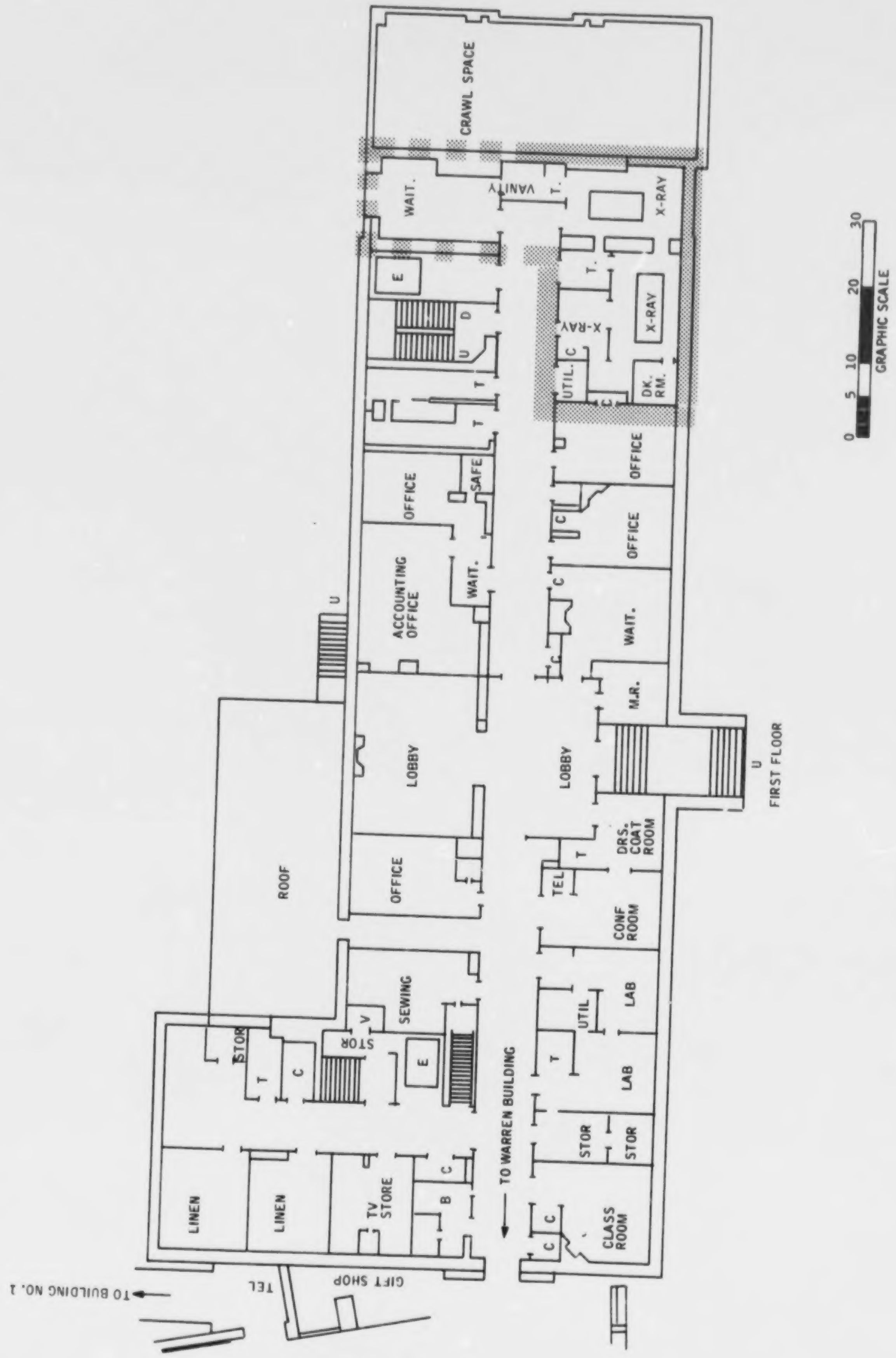
15
20
25
GRAPHIC SCALE

Figure A6. Diagnostic Radiology - Baker Memorial Building, Second Floor


CRAWL SPACE
WAIT.
VANITY
T.
X-RAY
E
D
U
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X-RAY
C
UTIL.
C
X-RAY
DK. RM.
OFFICE
SAFE
OFFICE
C
OFFICE
ACCOUNTING OFFICE
WAIT.
C
WAIT.
U
C
M.R.
LOBBY
LOBBY
U
FIRST FLOOR
ROOF
OFFICE
T
DRS. COAT ROOM
TEL
CONF ROOM
SEWING
STOR
V
E
UTIL
LAB
T
LAB
STOR
STOR
STOR
C
T
LINEN
LINEN
TV STORE
C
B
TO WARREN BUILDING
C
C
C
CLASS ROOM
GIFT SHOP
TEL
TO BUILDING NO. 1
0
5
10
20
30
GRAPHIC SCALE

Figure A7. Diagnostic Radiology - Phillips House

APPENDIX B

DETAILED PROCESS SEQUENCE NARRATIVES AND DIAGRAMS

APPENDIX B
DETAILED PROCESS SEQUENCE NARRATIVES AND DIAGRAMS

This appendix contains process sequence narrations and associated diagrams for the Diagnostic Radiology areas of White-1 and -2, Baker-1 and -2 and Phillips House.

Filing and reporting sequences are also detailed and diagrammed for White-2 and Baker-1 and -2.

WHITE-1 PROCESS SEQUENCE

The White-1 process sequence is diagrammed in Figure B1 and detailed in the following narrative.

1 Emergency ward physician examines patient and determines X-ray is necessary

1-2 Physician, nurse, or clerk fills out RRF; attaches EW admission slip

2-3 Patient is transported by messenger to White-1 Radiology via stretcher or wheel-chair, with RRF and admission slip

3-4 Requisition (RRF) is stamped (time clock) by the radiology receptionist, indicating patient arrival time

4-5 Receptionist checks admission slip for patient's insurance coverage and stamps the requisition in three places (X-ray control, medical records, and physician's copies) according to coverage

5-6 Patient's name, unit number, time of arrival, examination, and age is registered in a log book and the statistical day sheets

6-7 Technologist takes requisition from receptionist's desk, identifies patient, and proceeds to examination room

7-8 Examination is conducted

8-9 Darkroom technologist takes exposed films and processes them (3-1/2 minutes)

9-10 X-ray films are checked for quality by technologist and/or radiologist--retaken if necessary

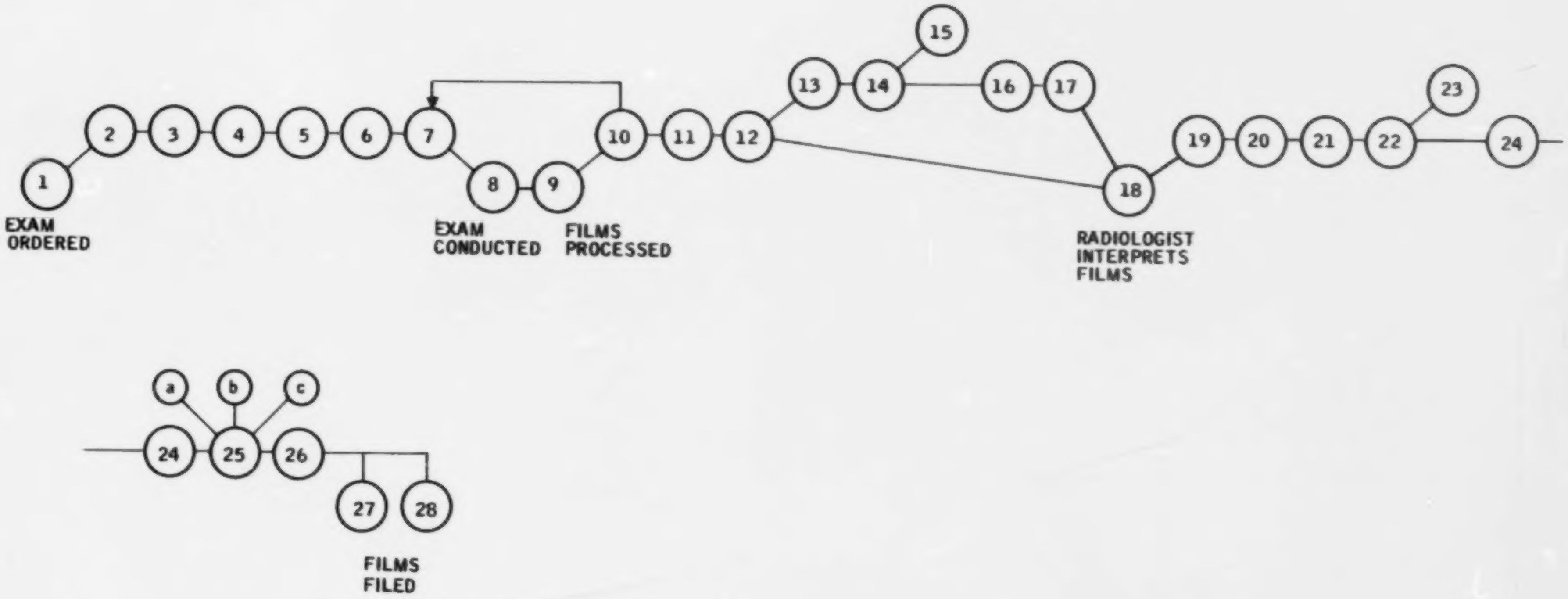

1
EXAM ORDERED
2
3
4
5
6
7
8
EXAM CONDUCTED
9
FILMS PROCESSED
10
11
12
13
14
15
16
17
18
RADIOLOGIST INTERPRETS FILMS
19
20
21
22
23
24
a
b
c
24
25
26
27
28
FILMS FILED

Figure B1. White-1 Emergency Ward Process Sequence

11-12 Radiologist puts X-rays on view box and checks requisition for patient's clinical history. If it reveals patient has had previous X-rays, they are obtained.

12-13 Receptionist or medical secretary calls W2 filing, and give unit number and patient's name

13-14 Medical secretary records in record book patient name, unit number, time call was made and stamps "film called" on medical records copy

14-15 W2 filing clerk returns call to report if films are available. If so, old films are placed in slot file, after recording current examination, date, and number of X-ray on master folder

14-16 W1 messenger picks up films on W2 and returns to W1.

16-17 Old films are inserted under loan envelope flap (new films are in loan envelope)

17-18 Radiologist is given entire envelope and proceeds to record interpretation onto Norelco dictaphone tape, on medical secretary's desk

18-19 Radiologist removes file room copy from RRF and inserts it into master folder

19-20 X-rays are then placed in a cart (alphabetically, by patient's last name), indicating that the X-ray has been interpreted

20-21 RRF is passed to medical secretary, who transcribes interpretation on RRF

21-22 Medical secretary removes physician's copy (unsigned) and places same in an envelope with the patient's name and destination

22-23 Messenger returns patient and envelope to Emergency Ward

22-24 File clerk removes X-ray film folder from cart together with the remaining portion of the RRF from the secretary's desk, and places both on staff radiologist's desk for final review and signature

24-25 Radiologist returns RRF to medical secretary for copies distribution as follows:

a. Medical records copy to EW for insertion into patient's medical chart

b. File report to file clerk to be inserted in patient's master folder

c. Insurance copy and attached admission slip to Radiological Associates (billing) office

25-26 File clerk removes folder from radiologist's desk and inserts file room report into folder

26-27 Films are filed numerically, according to the last two digits of the unit number, for a 24-hour period, after which they are filed permanently in W2 file room

26-28 If patient is in Overnight Ward (ONW), films are transferred across the consulting room. Films remain there until patient leaves ONW, at which time they are transferred to W2 permanent file. If patient becomes an inpatient, then films are transferred to the filing room serving the patient's hospital area.

WHITE-2 (INPATIENT) PROCESS SEQUENCE

The White-2 process sequence is diagrammed in Figure B2 and detailed in the following narrative.

1 Physcian (usually House Officer) decides patient needs X-ray

1-2 House Officer notes X-ray examination request in order book

2-3 House Officer fills out RRF, signs and hands to unit coordinator (UC)

3-4 Unit coordinator stamps RRF with addressograph plate

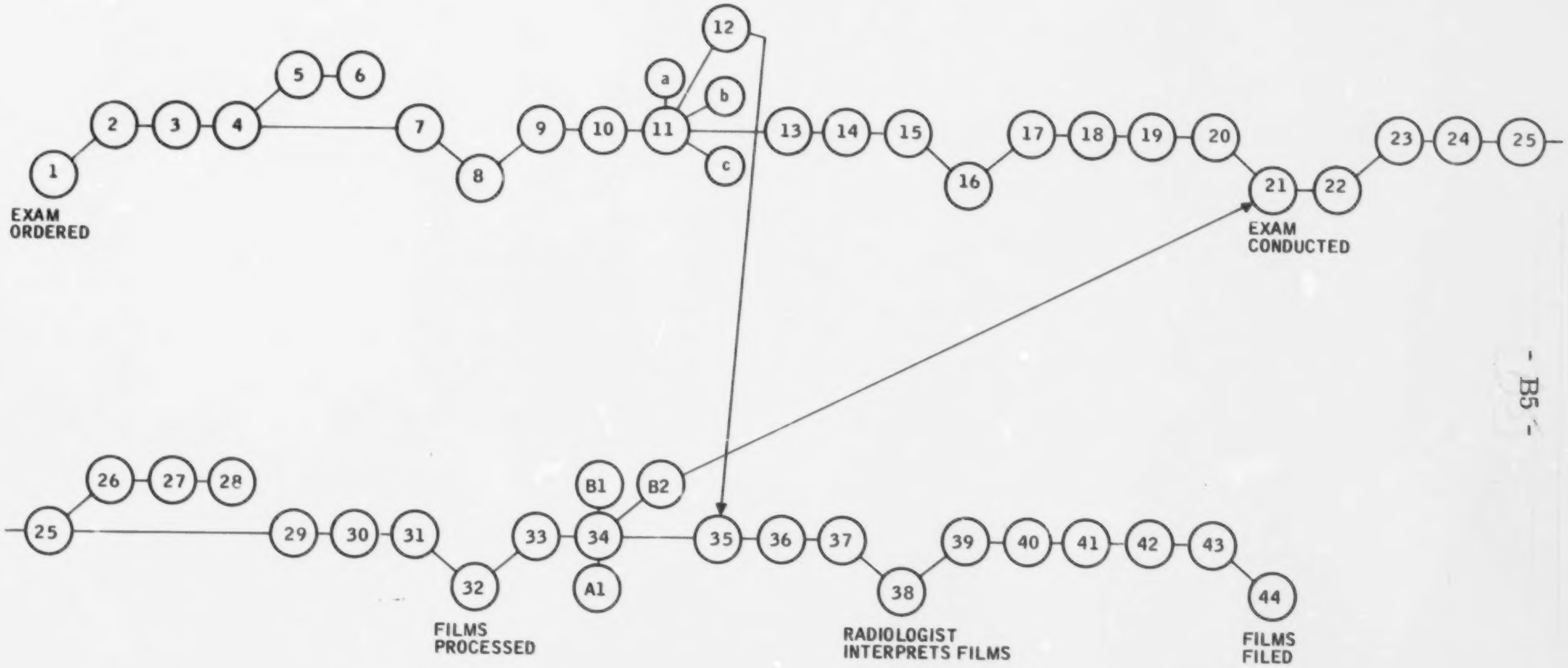
4-5 UC phones W2 receptionist for examination appointment - receptionist responds with an appointment time

5-6 UC notes examination appointment in SKUT sheet or travel book

4-7 For GI's or IVP's , RRF is hand-carried to W2 Radiology requisition box by 4:00 pm or by 8:00 am of day of examination for other examination types

7-8 At 5:00 pm appointment book is sent to W1 Radiology with a note stating how many examinations of what type can be scheduled for following morning. Physician is supposed to leave RRF if he schedules an examination. Evening personnel record examinations ordered for next day.

Fi, B2


1
EXAM ORDERED
2
3
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11
a
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c
12
13
14
15
16
17
18
19
20
21
EXAM CONDUCTED
22
23
24
25
25
26
27
28
29
30
31
32
FILMS PROCESSED
33
34
B1
B2
A1
35
36
37
38
RADIOLOGIST INTERPRETS FILMS
39
40
41
42
43
44
FILMS FILED

Figure B2. White-2 Process Sequence

8-9 Appointment book is returned to W2 the following morning

9-10 In the morning, head technologist sorts accumulated RRF's by examination type and requested date

10-11 RRFs sorted according to examination type and delivered to proper scheduler. Scheduler (one scheduler is assigned to each of the four examination types; IVP, chest, bones, GU) performs following operations:

a. Fills out dispatch card, flash card if examination is a fluoroscopy, and file room copy (if needed)

b. Codes RRF

c. Transfers RRF information to statistics daily sheet

11-12 File room clerk picks up file room copies (when patient is on floor) and takes back to file room, retrieves old films and reports and files them in holding file for new films

11-13 Scheduler refers to RRF pile, pulls top RRF, and calls floor to give advance notice to nursing personnel

13-14 Scheduler places corresponding patient dispatch slip on "pick up" dispatch book

14-15 Dispatcher signs out (time), takes dispatch slip and goes to floor

15-16 Dispatcher returns with patient, signs in and surrenders dispatch slip to scheduler

16-17 Scheduler removes accounting copy from patient RRF and stacks, to be sent to accounting

17-18 Scheduler attaches dispatch slip to RRF; technologist picks up RRFs

18-19 Technologist prepares room for examination (lead letters and numbers are placed over film)

19-20 Technologist matches RRF to patient (either verbally or by ID band)

20-21 Technologist transports patient to examination room

21-22 Examination is conducted -- patient is removed from examination room

22-23 Technologist initials RRF, enters number and size of film

23-24 Technologist enters examination completion time on dispatch slip

24-25 Technologist returns dispatch slip to scheduler

25-26 Scheduler places dispatch slip on "return" dispatch book

26-27 Dispatcher picks up dispatch slip, signs out

27-28 Dispatcher returns patient to floor

25-29 Technologist delivers exposed film to darkroom

29-30 Technologist places corresponding RRF in basket in quality control room

30-31 Technologist returns to examination room

31-32 Processing technologist at output of X-omat matches processed films with RRF, places films and RRF in new envelope

32-33 Processing technologist writes patient's name and unit number on envelope and hands to quality control

33-34 Quality control girl (QCG) judges film quality

a. Procedure if QCG judges film to be satisfactory:

(1) QCG puts films and RRF's back in envelope and files in QCR-FR partition file by patient's terminal unit number

b. Procedure if QCG judges film to be unsatisfactory:

(1) QCG discusses film with technologist

(2) RRF sent back to scheduler and patient is called back from floor

34-35 Filing clerk matches new film envelope and RRF to old film and report master in envelope

35-36 The two envelopes are then transferred to resident's viewing area

36-37 Appropriate films are displayed on alternators by file clerk

37-38 Resident interprets film and reports diagnosis into dictaphone. Staff radiologist may view film for checking at this time.

38-39 Medical secretary picks up dictaphone tape and types results on RRF

39-40 RRF returned to resident and resident signs (if wet reading, resident will call floor and give verbal report)

40-41 Typed RRF and films of unchecked cases are then given to staff radiologist for viewing and signature. RRF's of staff-checked cases are given to staff radiologist for signature.

41-42 Medical secretary dispenses RRF copies in routine manner

42-43 Films are then filed in consulting file until 6:00 pm

43-44 Films are then transferred to W2 file room for permanent filing (evening personnel finish up what day personnel did not do)

WHITE-2 FILING AND REPORTING SEQUENCE

The White-2 filing and reporting sequence is diagrammed in Figure B3 and detailed in the following narrative

1-2 File clerk (type 1) gets file room copy of RRF from the receptionist with patient information on it (from the RRF - which stays with receptionist).

2-3 File clerk (type 1) checks Kardex for any old films on patients

3-4 File clerk (type 1) retrieves old films and reports - going by unit number

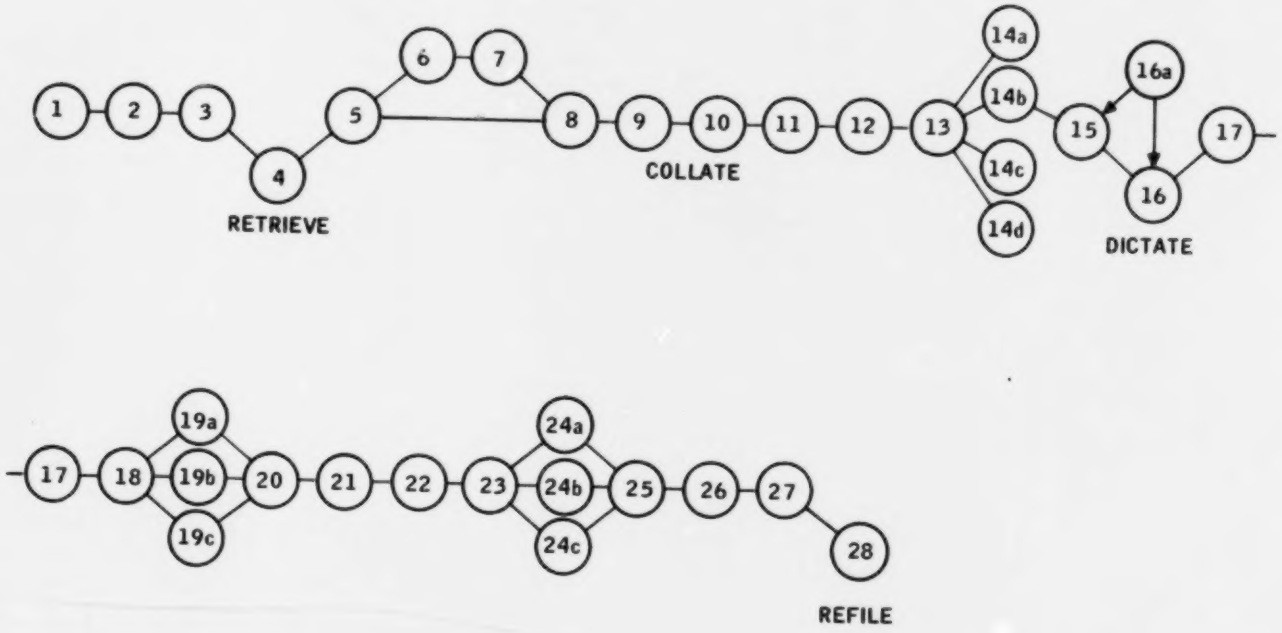
4-5 File clerk (type 1) files films in "holding file" and awaits new films. She records on white card in file that films have been pulled

For Bone and Chest Films

5-6 Technologist brings new films to quality control

6-7 X-omat processing man marks patient's name and unit number on new films envelope and gives to quality control girl

7-8 Quality control girl judges them and puts OK films and RRF files by unit number in slot file between Quality Control and File Room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REFILE

Figure B3. White-2 Process Sequence - Filing and Reporting

5-8 Technician takes envelopes with new films and RRF* directly to QCFR file by unit number

8-9 File clerk takes new films from slot in QCFR (next to filing area)

9-10 File clerk (type 1) collates old and new film

10-11 New films and RRF's are placed in a plastic envelope outside the old master envelope, with appropriate subspecialty old films

11-12 File clerk (type 1) logs into New Film Log Book patient's name, unit number, patient source, anatomical category

12-13 File clerk (type 2) takes collated films packet to Dodd Conference Room, recording in New Film Log Book actual time when sent over

13-14 File clerk (type 2) puts collated film packet into appropriate subspecialty "unread" slots by terminal digits of unit number.

a. Chest

b. GI

c. Bones

d. GU

14-15 File clerk (type 3) sets up films on appropriate alternators (labeled for each examination category)

16a Radiologist may receive films and RRF from W1 (of emergency patient subspeciality assigned to White).

15-16 Radiologist interprets films and dictates diagnosis.

16-17 Radiologist puts new RRF inside manila folder containing old reports.

17-18 Radiologist places new films into appropriate colored subspecialty envelope containing old films and puts them inside master folder, discarding plastic envelope.

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*RRF is minus accounting copy (dispatch clerk or receptionist keeps and sends to billing after patient is actually called.

18-19 Radiologist places "Master" envelope into "read section" of film subspeciality compartment (corresponding to new examination) - by examination (a) bones; (b) fluoroscopy; (c) chest. Under patient source BF2, -5, -6; W6-7; house patient; OPD.

19-20 Radiologist leaves stack of manila folders containing new RRF and old reports for medical secretary.

20-21 Secretary pulls tapes from dictaphones and transcribes (types) reports onto RRF.

21-22 Secretary brings typed reports to radiologist.

22-23 Radiologist checks and signs report copies.

23-24 Secretary tears copies apart and respective copies of reports are distributed four times a day [minus (a) accounting copies (orange and white) and (b) X-ray control copy (white) which remains with receptionist and is sent to Radiology Association.]

a. X-ray file room copy into manila folder with other reports.

b. Medical records copy to patient's chart (floor) and then to medical records upon discharge.

c. Physician's copy to attending physician.

24-25 Secretary takes pile of manila folders to Dodd Room.

25-26 File clerk (type 4) puts them inside appropriate "read" envelope packet and files in "consulting" file.

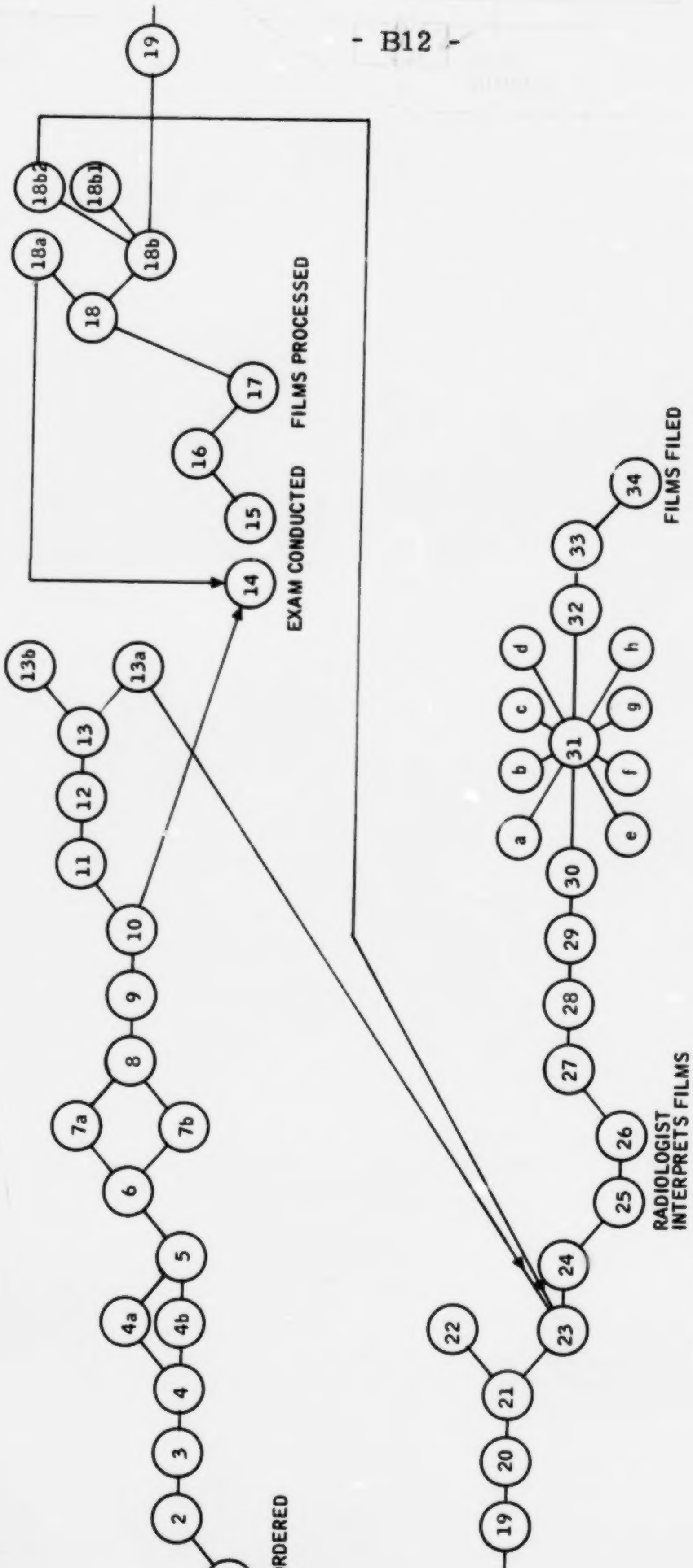
26-27 File clerk (type 4) brings back "read" Master envelopes (at end of day).

27-28 File clerk (type 5) finishes transferrals and refiles them in W2 filing where they are kept in the active file for six weeks (color coded each week).

BAKER-1 PROCESS SEQUENCE

The Baker-1 process sequence is diagrammed in Figure B4 and detailed in the following narrative.

1 Physician examines patient and decides X-ray examination is necessary .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EXAM CONDUCTED
FILMS PROCESSED
RADIOLOGIST INTERPRETS FILMS
FILMS FILED
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Figure B4. Baker-1 Process Sequence

1-2 Physician or external secretary calls B-1 medical secretary (B1MS) and arranges a patient examination appointment.

2-3 Physician or external secretary fills out a yellow route slip.

3-4 Physician or external secretary gives appointment time to patient and directs patient to B1 Radiology and either

a. Mails yellow route slip to B1MS

b. Instructs patient to handcarry yellow route slip to B1MS (if appointment is for same day).

4-5 Patient arrives at B1 radiology department and reports to B1 medical secretary (B1MS).

5-6 B1MS refers to yellow route slip and types RRF.

6-7 B1MS phones Central Filing (Baker basement) to determine if patient has old unit number.

a. If old unit number exists, B1MS dispenses of first two copies of outpatient RRF and completes remaining six copies.

b. If patient does not have an old unit number (patient is new) the total set of eight copies is completed and is given a unit number.

7-8 From completed RRF's B1MS pulls X-ray control copy and puts on technologist's shelf by B1MS desk.

8-9 B1MS buzzes technologist who picks up X-ray control copy, returns to examination room and prepares for patient.

9-10 Patient is ushered to dressing room and given dressing instructions.

10-11 Typed RRF is put in record folder and sent via dumb waiter to B1 ambulatory file clerk (B1AFC), located in B2 filing area.

11-12 B1AFC logs patient information in daily work sheet.

12-13 B1AFC refers to old film Kardex

a. If old films exist she retrieves old films

b. If there are no old films, B1AFC sends top two cards to B1MS for completion (who routes them to Central File).

10-14 Patient is escorted to examination room.

14-15 Examination is completed.

15-16 Technologist records number of films, size of films, and initials X-ray control copy.

16-17 Technologist transports exposed film to darkroom technician who processes film.

17-18 Technologist views films for quality

- a. If retakes are necessary patient is ushered back into examination room and process is repeated
- b. If films are satisfactory, technologist
  - (1) Informs aid to dress and release patient
  - (2) Sends X-ray control copy, yellow route slip and new film (packet) to B1 ambulatory file clerk (B1AFC), located in B2 file area.

18-19 Packet arrives in B1 filing section (located in B2) and B1AFC matches accounting copy to X-ray control copy and transfers film information to accounting copy.

19-20 B1AFC then cost codes accounting copy (may be done before examination).

20-21 B1AFC sends stack of completed accounting copies to B1MS.

21-22 B1MS attaches corresponding punched cards to accounting copies and mails them to accounting.

21-23 B1AFC inserts X-ray control copy into folder along with remaining corresponding RRF's.

23-24 RRF's, pertinent old films and reports, and new films are then assembled by B1AFC.

24-25 B1AFC transports assembled packet to radiologists' viewing room and files by patient's terminal unit number.

25-26 Radiologist pulls packet and interprets films, recording interpretation with dictaphone.

26-27 Radiologist puts old films and reports and new films into master envelope and files in "read" file by terminal unit number.

27-28 Radiologist places RRF's in stack for medical secretary.

28-29 Medical secretary picks up RRF's and dictaphone tape and types diagnostic report.

29-30 Medical secretary returns RRF to radiologist for signature.

30-31 Medical secretary dispenses RRF copies as follows:

- a. Hard yellow short copy sent to medical records, completed by B1MS if patient is new; if patient has had services before, copy is destroyed.
- b. Medical records file dummy (same as a).
- c. Accounting copy returned to B1MS who attaches appropriate IBM punched card for each code number and sends to Mosely-2 (hospital accounting).
- d. X-ray control copy sent to Radiological Associates.
- e. Medical records copy sent to central medical records filing office.
- f. Orange copy sent to Radiological Associates.
- g. Physician's copy mailed to physician.
- h. X-ray file copy filed in master envelope.

31-32 B1AFC transports completed master envelope back to filing area (B2).

32-33 B1AFC color codes master envelope to designate year of last film entry.

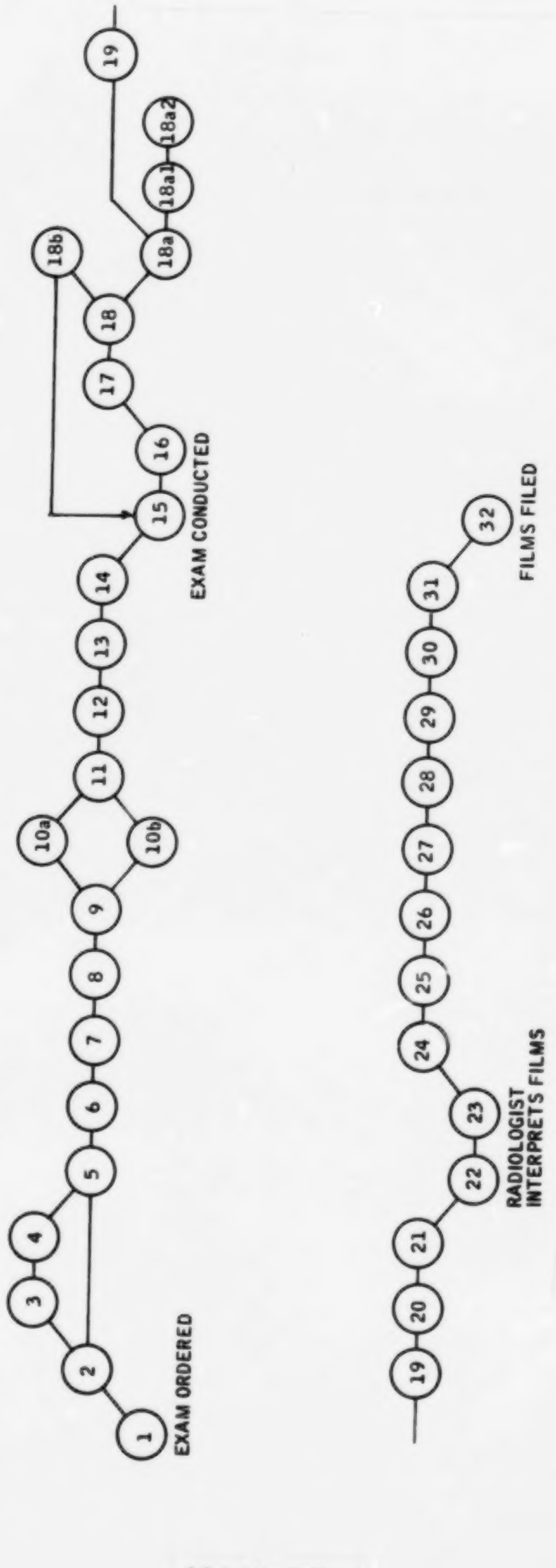
33-34 Master envelope is then transported to filing rack for permanent filing in B2 filing area.

BAKER-2 PROCESS SEQUENCE

The Baker-2 process sequence is diagrammed in Figure B5 and detailed in the following narrative:

1 Physician decides patient needs X-ray examination -- notifies unit coordinator.

Fig B5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RADIOLOGIST INTERPRETS FILMS
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FILMS FILED

Figure B5. Baker-2 Process Sequence

1-2 Unit coordinator (UC) types RRF (physician may print examination request, sign and UC will stamp with addressograph).

2-3 If fasting patients, UC calls B-2 Radiology for scheduled appointment.

3-4 Head technologist logs fasting patients in his log book.

4-5 2-5 RRF's are given to elevator operator who drops RRF's off at pickup box by elevator.

5-6 Head technologist then transfers RRF's to B2 file clerk (B2FC).

6-7 B2FC codes RRF's and enters patient information in log book.

7-8 B2FC removes file room copy and keeps.

8-9 From information on file room copy the patient information is transferred to statistics daily sheet.

9-10a Old film Kardex is referred to and old film and reports are retrieved if patient has any.

9-10b A new index card is made out if patient has not had previous films taken.

10-11 RRF transported back to B2 head technologist.

11-12 Head technologist then sorts RRF's according to examination type and distributes them to appropriate technologist.

12-13 When technologist is ready to examine patient he prepares dispatch slip from information on RRF and places it on a spindle sitting on head technologist's desk (dispatch slip has patient's name and floor and unit number).

13-14 Dispatcher picks up dispatch slip and brings patient.

14-15 Technologist matches RRF with patient and wheels patient into examining room.

15-16 Examination is conducted.

16-17 Technologist carries film back to darkroom and returns to room to prepare for next patient.

17-18 When technologist feels that films should be developed he returns to processing room and quality checks film

- a. If film is satisfactory, film and RRF's are taken to file room by technician.
    - (1) Patient transported to "return" side of hallway
    - (2) Dispatcher returns patient.
- b. If film is not satisfactory, patient receives another X-ray examination.

18-19 B2FC matches file room copy.

19-20 Daily log book is checkmarked.

20-21 Patient and film information is written on new film envelope.

21-22 New films, RRF, and old film and reports (if any) are then assembled and transported across the hall and filed in "unread" file by terminal digits of patient's unit number.

22-23 Radiologist interprets film and makes his report into dictaphone.

23-24 Radiologist places new film in master envelope and stacks RRF for medical secretary.

24-25 Medical secretary retrieves tapes and types report on RRF.

25-26 RRF's are transported to radiologist for signature.

26-27 Medical secretary retrieves RRF's and dispenses copies in routine manner.

27-28 The X-ray file copy is inserted into manila folder which contains all of the old reports.

28-29 Folder is inserted into master envelope along with new and old film.

29-30 Entire packet is transported to "read" file in temporary file room.

30-31 After 24 hours B2 file clerk picks up the master envelope, transports it to B2 file room area.

31-32 Master envelope is color tape coded and transported to permanent file (filed by patient's unit number).

BAKER-1 AND -2 FILING AND REPORTING SEQUENCE

The Baker-1 and -2 filing and reporting sequence is diagrammed in Figure B6 and detailed in the following narrative.

1-2 File clerk gets RRF:

- a. On B2: from head technologist minus X-ray control copy (been given to technologist).
- b. On B1: from B1 medical secretary minus X-ray control copy and first two copies if patient is not new.
- c. From W1: new film envelopes containing RRF (minus accounting copy).

2-3 File clerk:

- a. Codes RRF's.
- b. Logs information onto daily work sheet from X-ray file copy taken from RRF (may be done after examination).

3-4 File clerk copies information from daily sheets on to:

- a. 3 x 5 yellow index cards for Patient Index (new patient)
- b. Old Kardex record (old patient).

4-5 File clerk finds whether and when patient had old films from Patient Index File.

5-6 File clerk retrieves films and reports from B2 file room (or calls W2 file room where necessary for old films).

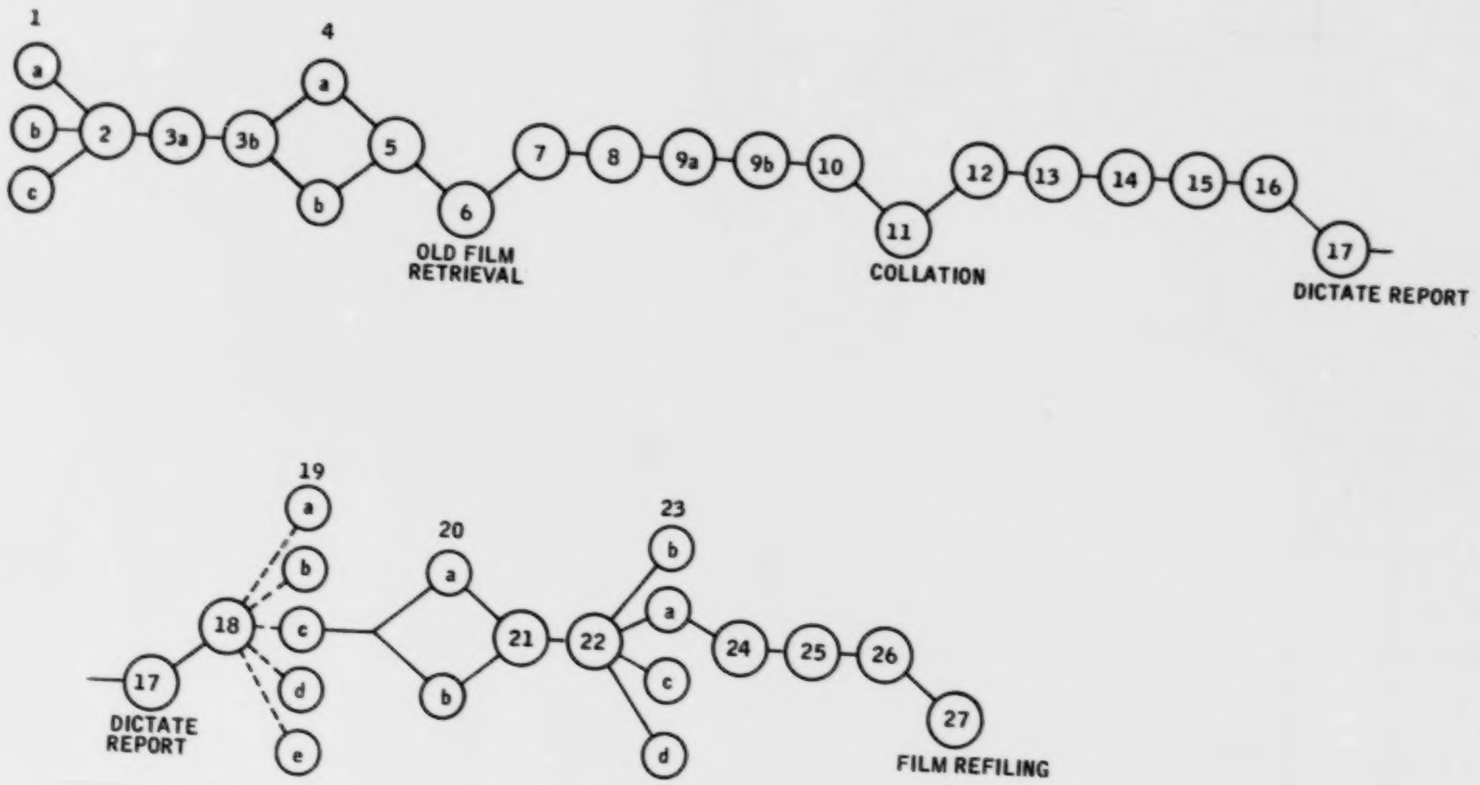
6-7 (B2) RRF transported back to B2 head technologist (examination conducted).

7-8 Technologist puts new films and X-ray control copy (and rest of RRF's for B2) in "new film" slot.

8-9 (B2) File clerk:

- a. Matches file room copy with rest of RRF and X-ray control copy.

Fig B6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FILM REFILING

Figure B6. Baker-1 and -2 Process Sequence -- Filing and Reporting

b. Checks off in daily log book.

9-10 File clerk puts patient's name, examination, amount of film, etc., on new film envelope from daily sheet and X-ray control copy.

10-11 File clerk collates old and new films, matching report copies.

11-12 File clerk puts accounting copy (with added information from X-ray control copy) into special box (to be sent to Mosely-2 at end of day).

12-13 File clerk puts X-ray control copy in with rest of RRF.

13-14 File clerk clips pertinent old films, reports, and RRF under flap of master envelope.

14-15 File clerk takes collated packet to radiologists' boxes and places by unit number in "unread" part (top file of viewing room file cabinet).

15-16 Radiologist takes his assigned films to "unread section" of temporary cart file in his viewing area.

16-17 Radiologist dictates diagnoses, referring to old films and old reports.

17-18 Radiologist puts new films and the relevant old films and corresponding RRFs inside master envelope.

18-19 Radiologist puts these envelopes by unit number into either:

a. "Read" part of cart file

b. Bottom half of Viewing Room (VR) file cabinet.

c. VR respiratory unit file.

d. VR pediatrics file.

e. VR PH2 Coronary Care Unit as appropriate.

19-20 Radiologist puts RRF:

a. In stack for medical secretary (B1) or

b. Inside master envelope for medical secretary (B2)

20-21 Secretary picks up RRF's, pulls dictaphone tapes, transcribes (types) reports onto RRF's.

21-22 Radiologist reads typed reports and signs.

22-23 Secretary retrieves RRF's (from radiologist) and dispenses of:

- a. X-ray file room copy into manila folder
- b. Medical records copy to medical records (i.e., patients chart till discharge for B2)
- c. Physician's copy to attending physician (picked up three times/day by messenger)
- d. Once per day from house mail X-ray control (white) and orange copy to Radiological Associates (B1 first send to B1 secretary)

23a-24 File clerk or secretary puts manila folder inside master envelope and puts this into "read" part of VR file cabinet

24-25 File clerk checks "read" envelopes and pulls those that are complete and have been in VR at least 24 hours

25-26 File clerk wheels these envelopes back to file room

26-27 File clerk refiles these films and reports

PHILLIPS HOUSE PROCESS SEQUENCE

The Phillips House process sequence is diagrammed in Figure B7 and detailed in the following narrative.

1 Physician examines patient and prescribes radiographic examination

1-2 Physician writes out RRF and signs

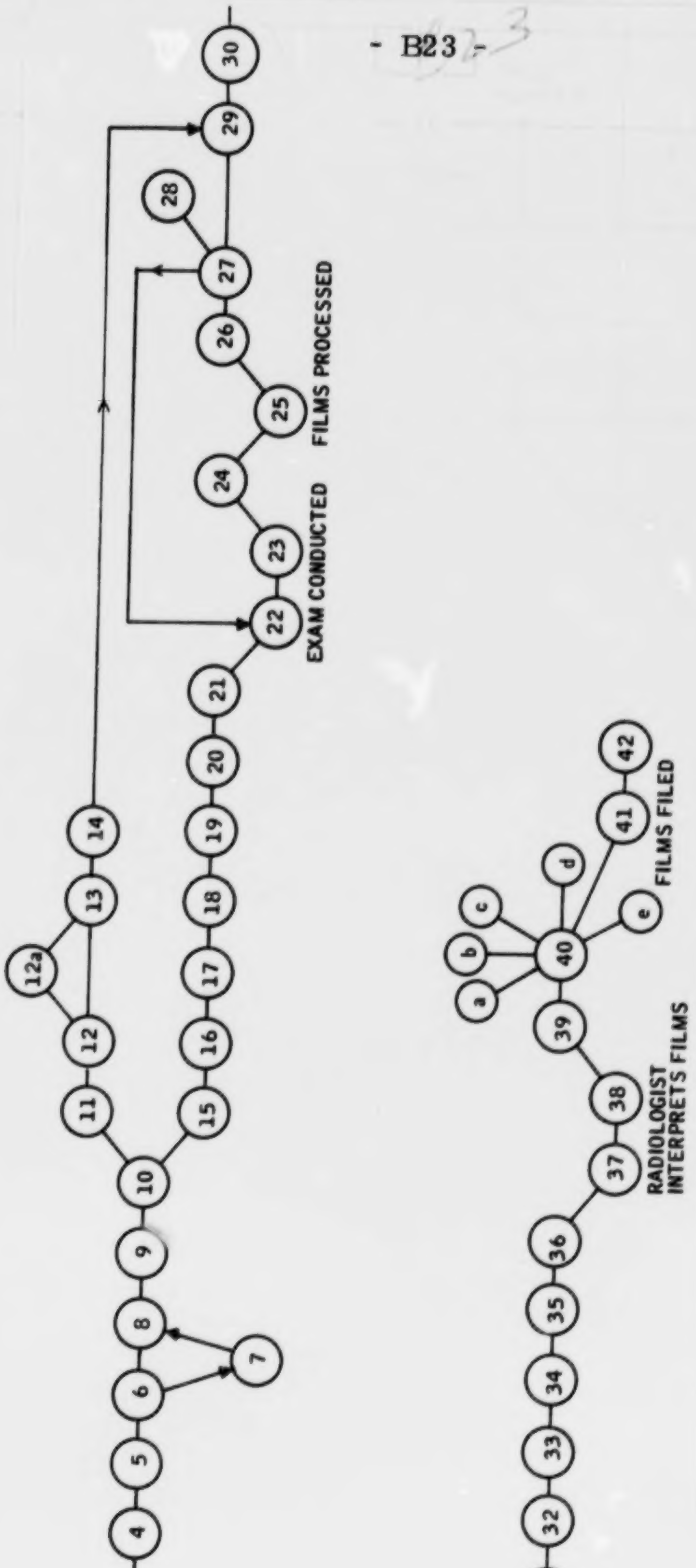
2-3 Physician hands RRF to unit coordinator (UC)

3-4 UC stamps RRF with addressograph and does one of the following:

- a. If patient requires pre-examination preparation UC calls PH radiology department (PHRD) (fasting cases only) and schedules examination, then stacks RRF on pile to be sent to PHRD at end of shift
- b. If patient does not require pre-exam preparation, UC may send RRF to PHRD without advance notice (RRF may be held to accompany patient to PHRD)

Fig B7

157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EXAM CONDUCTED
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RADIOLOGIST INTERPRETS FILMS
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FILMS FILED
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Figure B7. Phillips House Process Sequence

4-5 UC notes patient's examination on

- a. SKUT sheet
- b. Travel book
- c. Patient's Kardex (fasting card)

5-6 RRF's are hand-carried to PH admitting office at end of day

6-7, 7-8 At 5:00 pm appointment book is hand-carried to White-1 RD and returned the following morning (a provision for doctors who make evening rounds to schedule patients)

6-8 PH night supervisor transports night RRF's to PHRD for morning personnel

8-9 Head technologist arrives in morning and reviews RRF appointment book (which lists examinations only and not their time slots) and sorts RRF's

9-10 Head technologist tears file room copy from RRF's

10-11 PH file room clerk (PHFRC) picks up file room copies of RRF's and returns to PH file room in Baker-2

11-12 PHFRC refers to file room copy and old film Kardex file

- a. If patient has old films she retrieves them either by going directly to file room or by making a phone requisition if old films are in White filing area

12-13 PHFRC pulls pertinent old films and reports and transports them to PHRD

13-14 Nonpertinent old films and reports are filed in slot file until new films are received from PHRD

10-15 PH technologist checks received RRF's against list of scheduled patients

15-16 PH technologist notifies those nursing stations who have scheduled patients but have not sent RRF's

16-17 Nursing stations send RRF's

17-18 From the RRF's a daily work log is drawn up

18-19 Technologist refers to daily log for patient

19-20 Technologist calls floor for patient

20-21 Technologist checkmarks log book to indicate patient has been called

21-22 Patient arrives in PHRD

22-23 Examination is conducted -- patient waits

23-24 Technologist initials RRF, writes number and size of film exposed

24-25 Aide processes film

25-26 Aide returns film to technologist

26-27 Technologist quality-checks films. If films not acceptable, patient is re-X-rayed

27-28 Nurse from patient origination point is instructed to retrieve patient (via phone call). Patient is returned to floor.

27-29 New films are collated with old films and RRF

29-30 New and old films, with RRF, are hand-carried to PH radiology filing room on Baker-2 (including portable RRF's, to be done by Baker-2 portable technologist)

30-31 Filing clerk writes cost control number, examination code, and date on RRF's; date and examination on master envelope

31-32 File clerk then enters patient and film information on daily sheet

32-33 RRF's are put in new film envelope

33-34 Pertinent old films are pulled from master envelope and collated, along with new film envelope and RRF

34-35 New film examination type and date are entered on old film index card and filed in Kardex

35-36 The packet (pertinent old films, new films, corresponding RRF's) is then delivered to the radiologist (rest of old films stay in master envelope)

36-37 Radiologist interprets film in viewing room, dictating report

37-38 Medical secretary retrieves tapes and transcribes report on RRF forms

38-39 Completed RRF copies then given to radiologist for signature

39-40 Medical secretary retrieves RRF and dispenses remaining copies as follows:

a. Accounting copy to tabulating in White-1

b. X-ray control copy is attached to orange copy and sent to Radiological Associates

c. Green copy goes to patient's floor and inserted in patient's medical record -- if patient has been discharged it goes to medical records

d. X-ray file copy is inserted into master envelope

e. Physician copy sent by hospital mail back to physician

40-41 Old films, new films, and X-ray file copy are placed in color-coded master envelope, year coded by color tape and filed by patient's unit number

41-42 At end of day daily sheet is filed in filing room

161 Verso blank

APPENDIX C
FILM FILING SYSTEM

APPENDIX C
FILM FILING SYSTEM

FILING METHODOLOGY

The present film filing methodology at MGH is outlined in Table C1. Probable changes in this methodology to be made in the near future are listed in Table C2.

FILING AREAS

Radiology Filing and storage areas in White-2, -3 and -14 and Baker-2 are shown in Figures C1 through C4.

FILM FILE COLOR CODES

Various means of color coding to expedite filing organization have evolved in the two main file areas. In both B2 and W2, the year of the latest film entry is characterized by the application of a particular colored tape strip to the outside of the folder. In addition, on W2 films of a particular week residing in the six-week "active file" are designated by a characteristic color tape. Other designations are as follows:

- Baker-2 (Baker in- and outpatients, Phillips House and all Pediatrics)
  1) Tape Colors
     Pink - Orthopedics
     Yellow and red - Post-mortems
     Dark blue - Teaching Collection (or circled TC in corner of envelope for Pediatrics)
  2) Envelope Colors (Master Folders)
     Light blue - Pediatrics
     Tan - All others
- White-2 (In- and outpatients)
  1) Tape Colors
     Red - Stat cases
     Yellow and red - Post-mortems

Dark blue - Teaching Collection
Black - Staff and Clinics
Blue - House patients

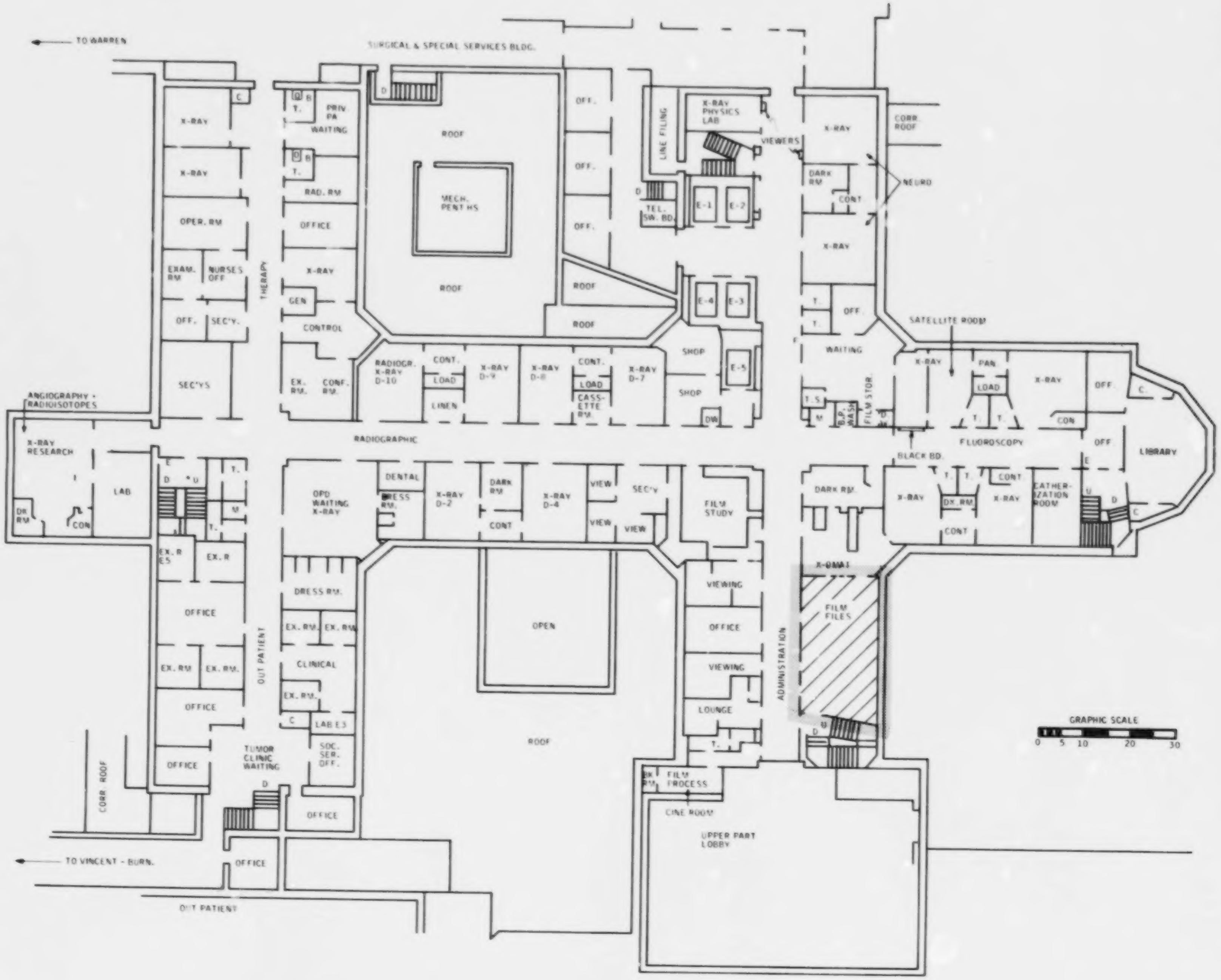
2) Envelope Colors
   (a) Master Folders
       Light blue - Pediatrics
       Orange - Shriner-Burns
       Tan - All others - with two terminal digits and middle digit of patient's unit number represented by color squares along folder edge, plus:
       (i) Green envelope border - clinic patients
       (ii) Pink envelope - inpatients
   (b) Subspecialty Envelopes (inserted in master folder)
       Gray - GI-Fluoroscopy
       Orange - GU-IVP
       Yellow - Bones
       Brown - Chest
       Pink - Stat

Table C1. Present Areas and Methodology for Filing Films (excluding cine, angio, isotope, and neuroradiology films)

Location and Description	Contents	Organizational Method
Storage		
Teaching Collection W3	Teaching films from all areas to 1937	By pathology and anatomical area
W14	2-5 year old master envelopes (MEV) of White outpatients	By unit number within each year
	1-5 year old MEV of White inpatients	
Interim Filing		
W3 Clinic films	White outpatient MEV to 1 year old	By terminal digit unit number within the year
W2 Main file room		
Regular file	White inpatient MEV 6 weeks to 1 year old	By terminal digit unit number within the year
"Active file"	White in- and outpatients films to 6 weeks old with older MEV	By terminal digit unit number within each week
Main file room B2	B1, B2, PH. MEV back 5 years	By unit number within each year
	Pediatrics MEV back 4 years	By first three numbers of unit number within each year
Temporary Filing		
B1, B2		
Radiologists portable cart (in offices)	New films and pertinent films from MEV	Slots: read; unread; stat readings
Holding files (file room)	MEV awaiting new films or films loaned out	By unit number
Loan-out "file" (file room)	Films requested	Slots: outside hospital requests; within hospital requests
Pediatrics reading room (portable cart)	New films and pertinent old films	Slots: unread-classified by reading radiologist and unit number; read-classified by unit number
Viewing Room		
Main wall file	New films and pertinent old films	Divisions: unread-classified by reading radiologist and unit number ; read-classified by unit number
Smaller wall file	Read films packet	Divisions: respiratory unit; Pediatrics; PH2 coronary care unit
W1 File cart (radiologists viewing room)	New films and available and pertinent old films	Slots; films not dictated (unread stats); repeats; fluoroscopy; dictated films (classified alphabetically)
W2 Dodd Conference room		
"Unread" film file carts	New films and pertinent subspecialty old films	Slots; chest; bones; GI; GU-classified by terminal digits of unit number
"Read" carts	New films and pertinent subspecialty old films	Slots: chest; bones; fluoroscopy within Bulfinch-2, 5, 6, White-6, 7, house, OPD; categories
W2 Quality Control		
Hallway partition	New films	Slots: chest seen by technologist; not seen by technologist
File room partition	New films	Slots: stat cases; quality checked films; classified by unit number
Loan-out "file" (hallway partition)	Requested films	Classified by label
Holding file (file room)	MEV awaiting new films	By unit number

Table C2. Probable Changes in Areas for Filing Films Pending Gray Building Move

Location and Description	Contents	Organizational Method
Storage		
Gray Building **Sub-basement archives**	**White in- and outpatients 6 weeks to 7 year old MEV**	By color coded terminal digit unit number within each year
Teaching collection W2 file area	**Same**	**Same**
W14	**MEV from Baker and PH**	**By terminal digit unit number**
Interim Filing		
Gray Building Second-floor work room active file	**White in- and outpatients - films to six weeks old**	By terminal digit unit number
B2 Main file - same	Same	Same
Temporary Filing		
B1, B2 - same	Same	Same
W1	Will have own file area and diagnoses will be dictated, transcribed, and distributed on W1	
Gray Building Separate viewing rooms GI GU Chest Bone	New films and pertinent sub-specialty old films	Categories: unread; read films packets
Conference room 24-hour "ready access" file	Ready new films packets	
Work Room Loan out "file"	Requested films	Films signed in and out (on MEV and loan envelope) at separate desks
Holding "file"	MEV awaiting new films	


TO WARREN
SURGICAL & SPECIAL SERVICES BLDG.
X-RAY
X-RAY
OPER. RM
EXAM. RM
NURSES OFF
OFF.
SEC'Y.
SEC'YS
THERAPY
PRIV PA WAITING
T.
B
RAD. RM
OFFICE
X-RAY
GEN
CONTROL
EX. RM.
CONF. RM.
ROOF
MECH. PENT HS
ROOF
RADIOGR. X-RAY D-10
CONT.
LOAD
LINEN
X-RAY D-9
X-RAY D-8
CONT.
LOAD
CASS-ETTE RM.
X-RAY D-7
SHOP
SHOP
DW
E-1
E-2
E-3
E-4
E-5
OFF.
OFF.
OFF.
ROOF
ROOF
LINE FILING
X-RAY PHYSICS LAB
TEL. SW. BD.
VIEWERS
X-RAY
DARK RM
CONT
X-RAY
NEURO
CORR. ROOF
T.
OFF.
WAITING
T.S.
M
B.P. WASH
FILM STOR.
SATELLITE ROOM
X-RAY
PAN
LOAD
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X-RAY
CON
OFF.
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LIBRARY
OFF.
FLUORDSCOPY
BLACK BD.
DARK RM.
X-RAY
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CATHER-IZATION ROOM
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E
ANGIOGRAPHY + RADIOISOTOPES
X-RAY RESEARCH
DK RM
CON
LAB
RADIOGRAPHIC
OPD WAITING X-RAY
DENTAL
DRESS RM.
X-RAY D-2
DARK RM
CONT
X-RAY D-4
VIEW
VIEW
SEC'Y
VIEW
FILM STUDY
X-OMAT
FILM FILES
ADMINISTRATION
VIEWING
OFFICE
VIEWING
LOUNGE
T.
DK RM
FILM PROCESS
CINE ROOM
UPPER PART LOBBY
OPEN
ROOF
DRESS RM.
EX. RM.
EX. RM.
CLINICAL
EX. RM.
C
LAB E3
SOC. SER. OFF.
TUMOR CLINIC WAITING
OUT PATIENT
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OFFICE
OFFICE
OFFICE
CORR. ROOF
TO VINCENT - BURN.
OUT PATIENT
GRAPHIC SCALE
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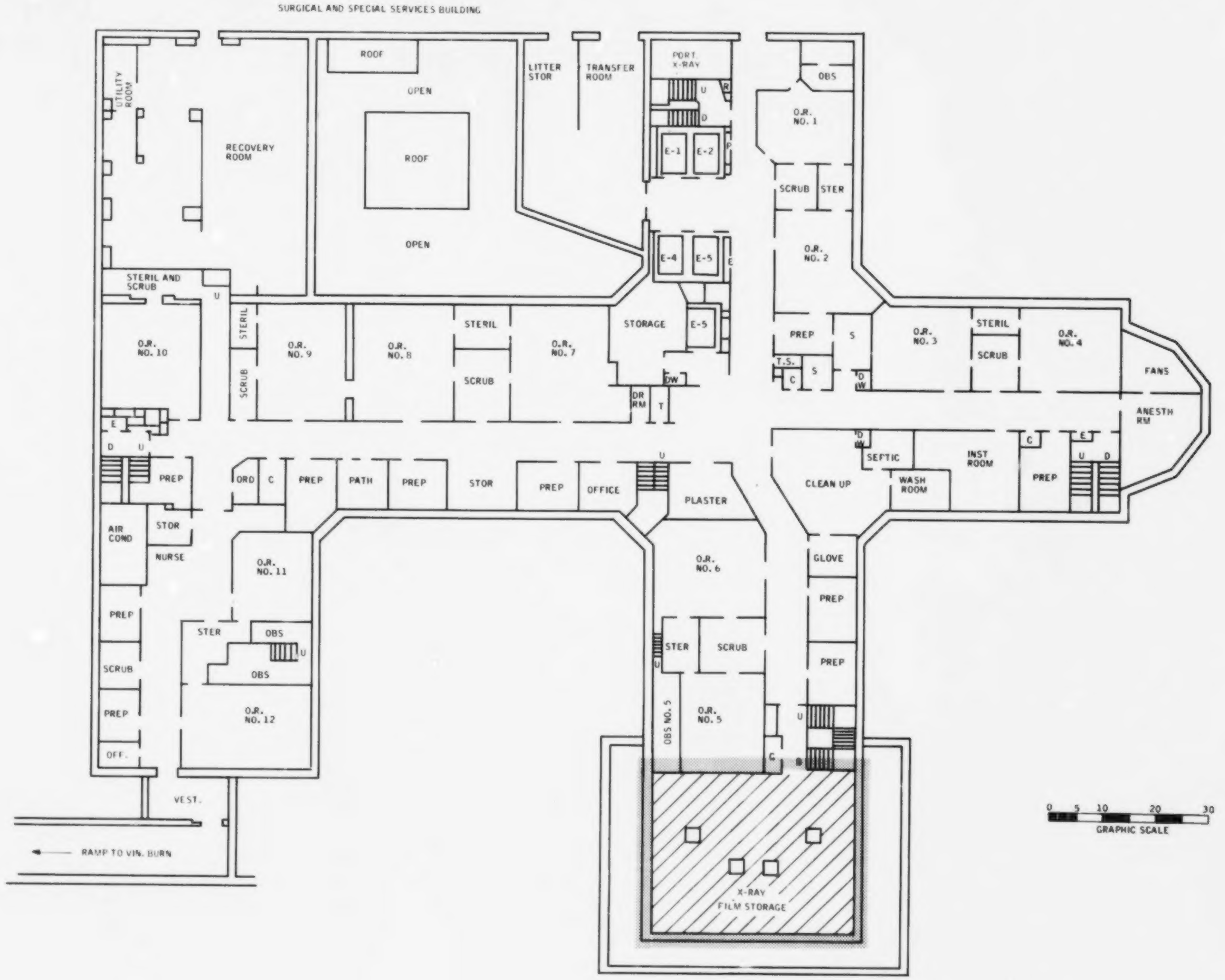
30

Figure C1. Radiology Filing and Storage - White Memorial Building, Second Floor


SURGICAL AND SPECIAL SERVICES BUILDING
UTILITY ROOM
RECOVERY ROOM
ROOF
OPEN
ROOF
OPEN
LITTER STOR
TRANSFER ROOM
PORT. X-RAY
E-1
E-2
OBS
O.R. NO. 1
SCRUB
STER
O.R. NO. 2
E-4
E-5
E-5
STERIL AND SCRUB
O.R. NO. 10
STERIL
SCRUB
O.R. NO. 9
O.R. NO. 8
STERIL
SCRUB
O.R. NO. 7
STORAGE
DW
DR RM
T
PREP
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T.S.
C
S
DW
O.R. NO. 3
STERIL
SCRUB
O.R. NO. 4
FANS
ANESTH RM
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D
U
PREP
ORD
C
PREP
PATH
PREP
STOR
PREP
OFFICE
PLASTER
CLEAN UP
SEPTIC
WASH ROOM
INST ROOM
C
PREP
AIR COND
STOR
NURSE
O.R. NO. 11
STER
OBS
OBS
O.R. NO. 12
PREP
SCRUB
PREP
OFF.
VEST.
RAMP TO VIN. BURN
O.R. NO. 6
STER
SCRUB
OBS NO. 5
O.R. NO. 5
GLOVE
PREP
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C
X-RAY FILM STORAGE
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20
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GRAPHIC SCALE

Figure C2. Radiology Filing and Storage - White Memorial Building, Third Floor

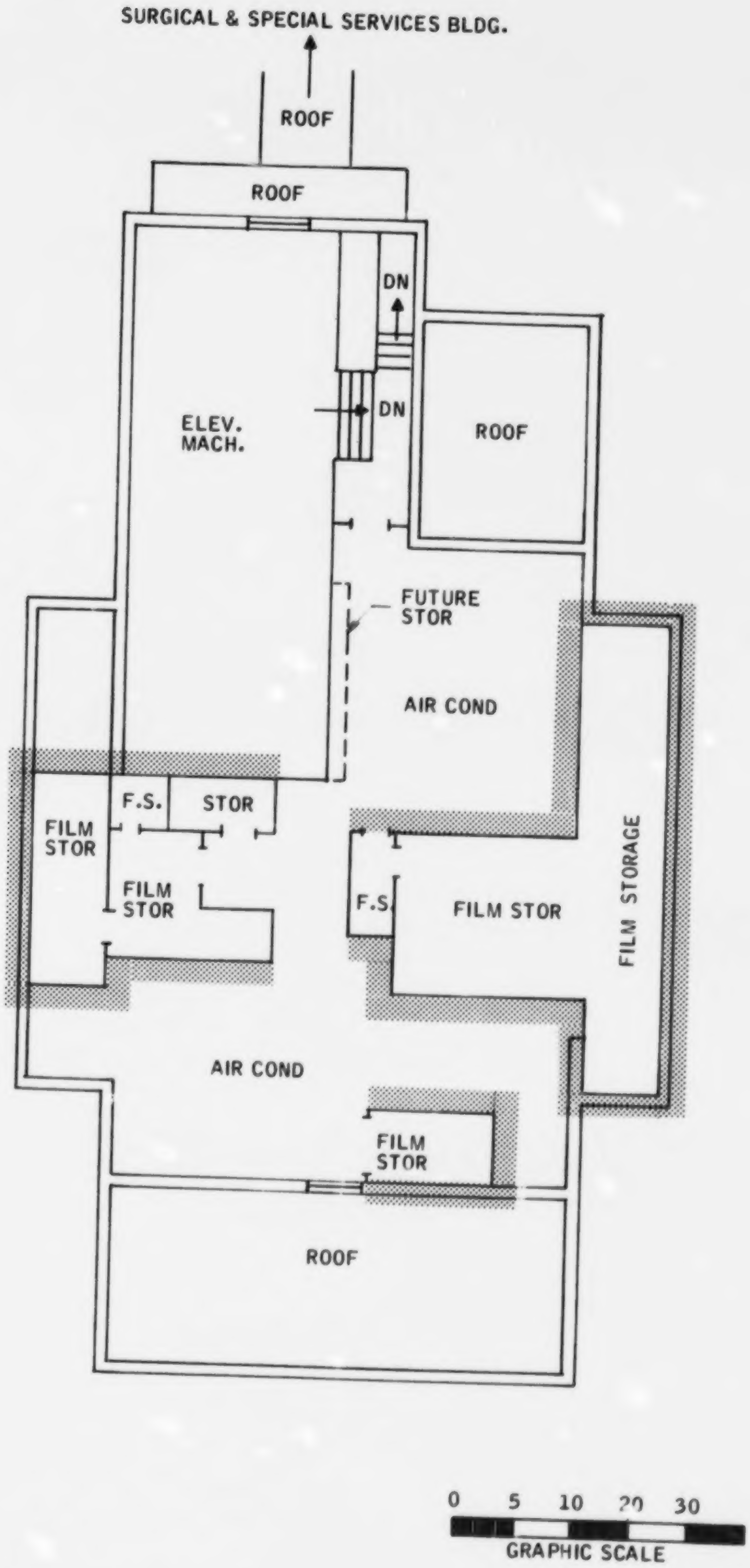
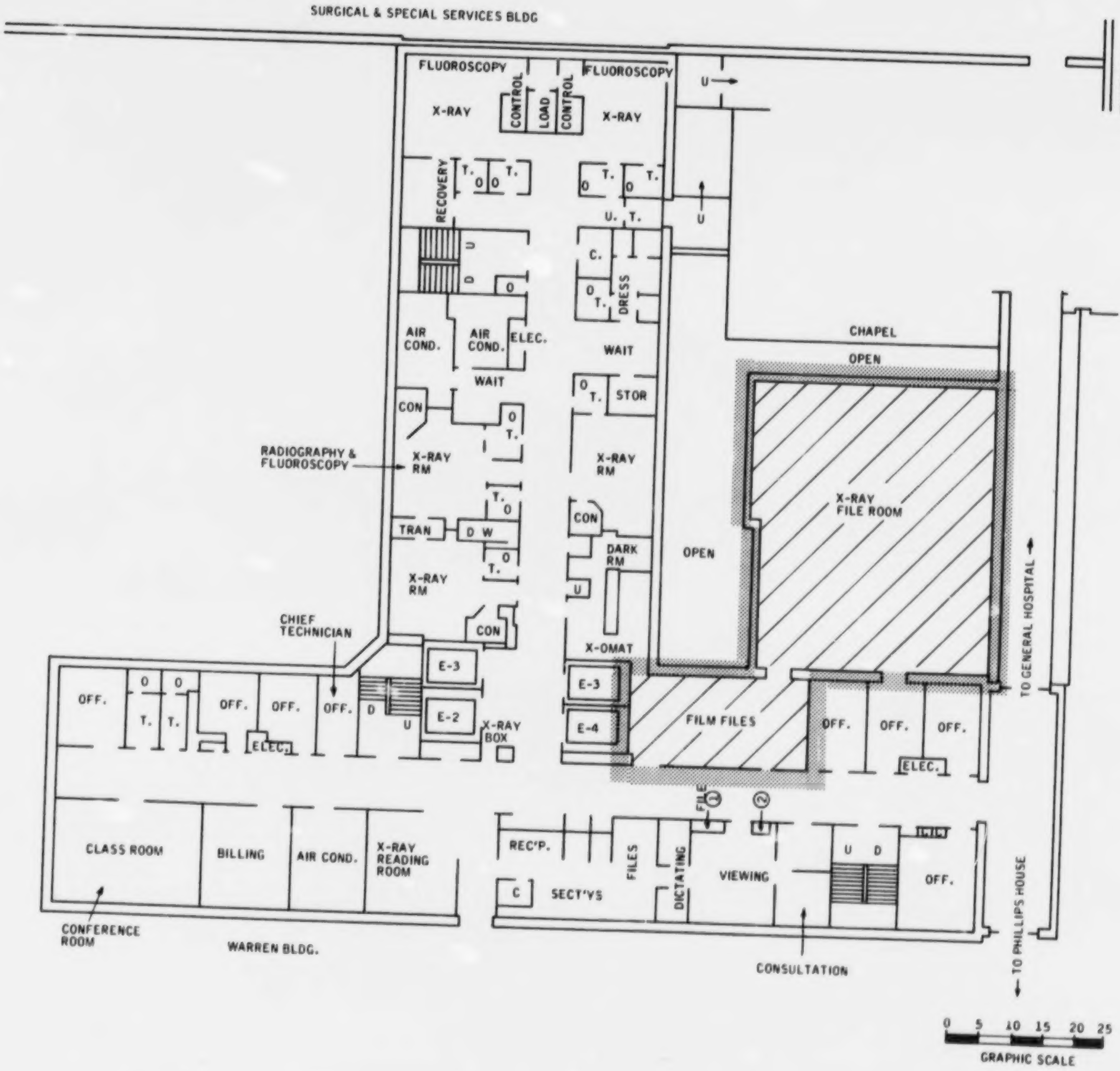

SURGICAL & SPECIAL SERVICES BLDG.
ROOF
ROOF
DN
DN
ELEV. MACH.
ROOF
FUTURE STOR
AIR COND
F.S.
STOR
FILM STOR
FILM STOR
F.S.
FILM STOR
FILM STORAGE
AIR COND
FILM STOR
ROOF
0 5 10 20 30
GRAPHIC SCALE

Figure C3. Radiology Filing and Storage - White Memorial Building, Fourteenth Floor


SURGICAL & SPECIAL SERVICES BLDG
WHITE BLDG.
FLUOROSCOPY
FLUOROSCOPY
X-RAY
CONTROL
LOAD
CONTROL
X-RAY
U
RECOVERY
T.
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AIR COND.
AIR COND.
ELEC.
WAIT
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CHAPEL
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T.
STOR
RADIOGRAPHY & FLUOROSCOPY
X-RAY RM
X-RAY RM
X-RAY FILE ROOM
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D W
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O
X-RAY RM
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CON
X-OMAT
CHIEF TECHNICIAN
E-3
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E-2
E-4
FILM FILES
TO GENERAL HOSPITAL
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SECT'YS
CONFERENCE ROOM
WARREN BLDG.
CONSULTATION
TO PHILLIPS HOUSE
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25
GRAPHIC SCALE

Figure C4. Radiology Filing and Storage - Baker Memorial Building, Second Floor

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APPENDIX D
PATIENT AND EXAMINATION LOAD STATISTICS

APPENDIX D
PATIENT AND EXAMINATION LOAD STATISTICS

Summaries of various MHG patient and examination loads are presented in Figures D1 through D7 and Tables D1 through D5.

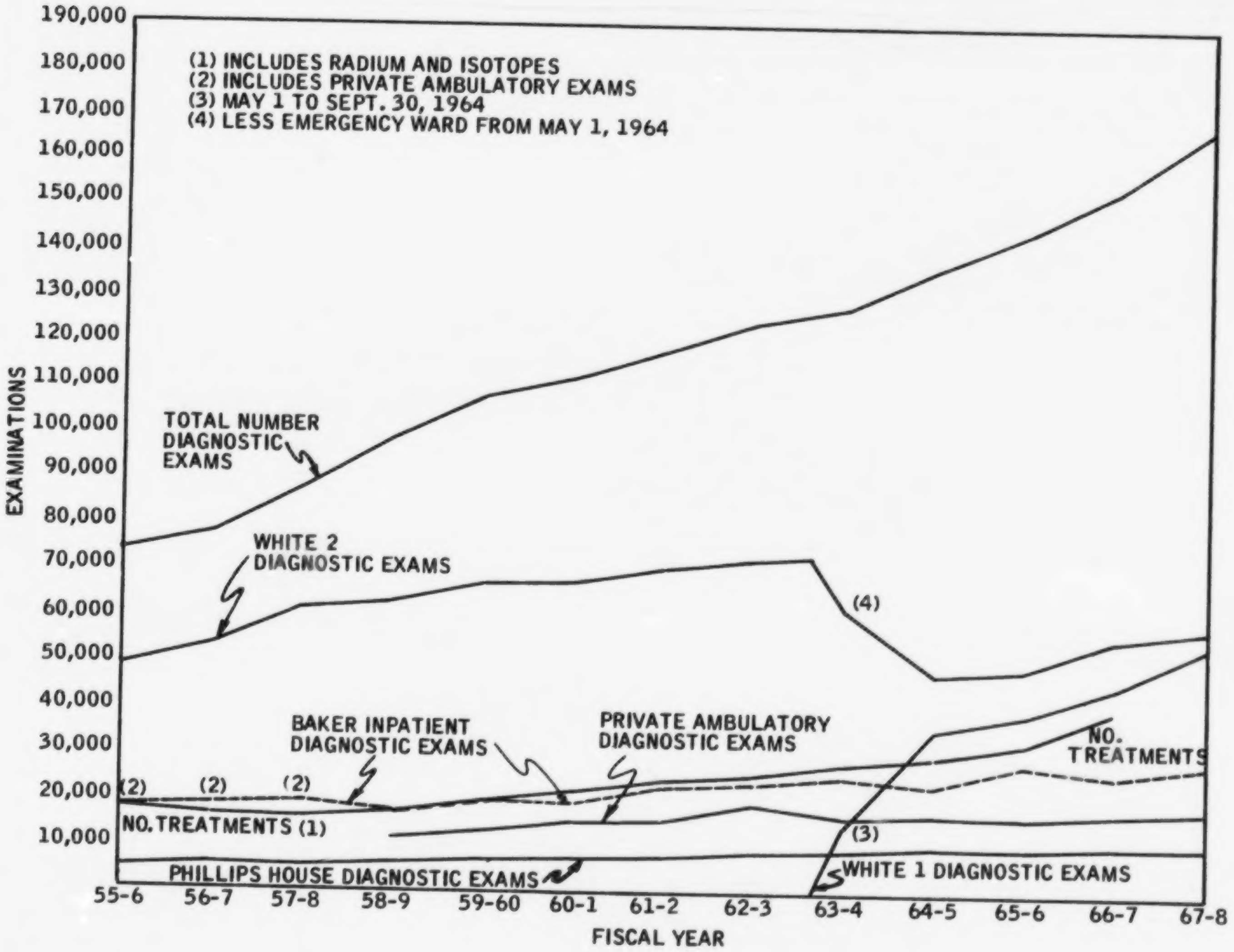


Figure D1. Diagnostic Examinations

Fig D2 71

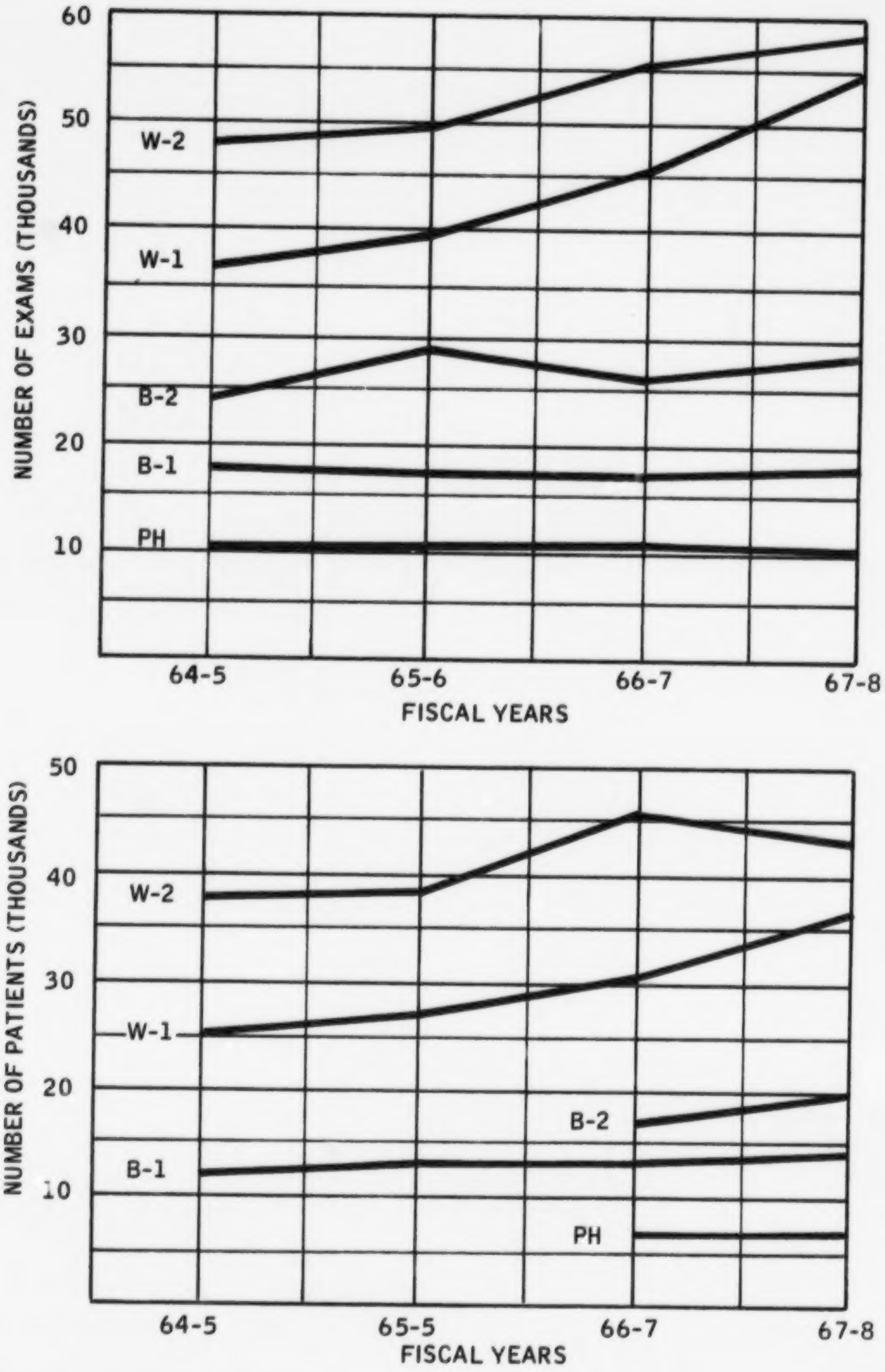


Figure D2. Number of Patients and Examinations per Year

[illegible] D3

Table D1. MGH Patients and Examinations per Year

Area	Fiscal Year	No. of Patients	No. of Examinations
White - 1	1964-65	25, 450	36, 519
White - 2		37, 825	47, 936
Baker - 1		12, 087	17, 871
Baker - 2			24, 100*
Phillips House			10, 200*
Total			137, 884
White - 1 } Footnote 1	1965-66	27, 060	39, 295
White - 2		38, 439	49, 434
Baker - 1		13, 268	17, 312
Baker - 2			28, 800*
Phillips House			10, 300*
Total			145, 365
White - 1 } Footnote 2	1966-67	30, 476	45, 493
White - 2		45, 070	55, 301
Baker - 1		13, 203	17, 345
Baker - 2		17, 188	26, 031
Phillips House		6, 648	10, 599
Total			154, 769
White - 1 } Footnote 2	1967-68	36, 410	54, 458
White - 2		43, 406	58, 099
Baker - 1		14, 099	17, 661
Baker - 2		19, 769	28, 374
Phillips House		6, 649	10, 048
Total			168, 640

* Estimate

1 (House, Clinics, Staff, Research, EW, ONW)

2 (House, Clinics, Staff, Research, EW, ONW, PH, B1, B2, Eye and Ear)

Fig D3 176

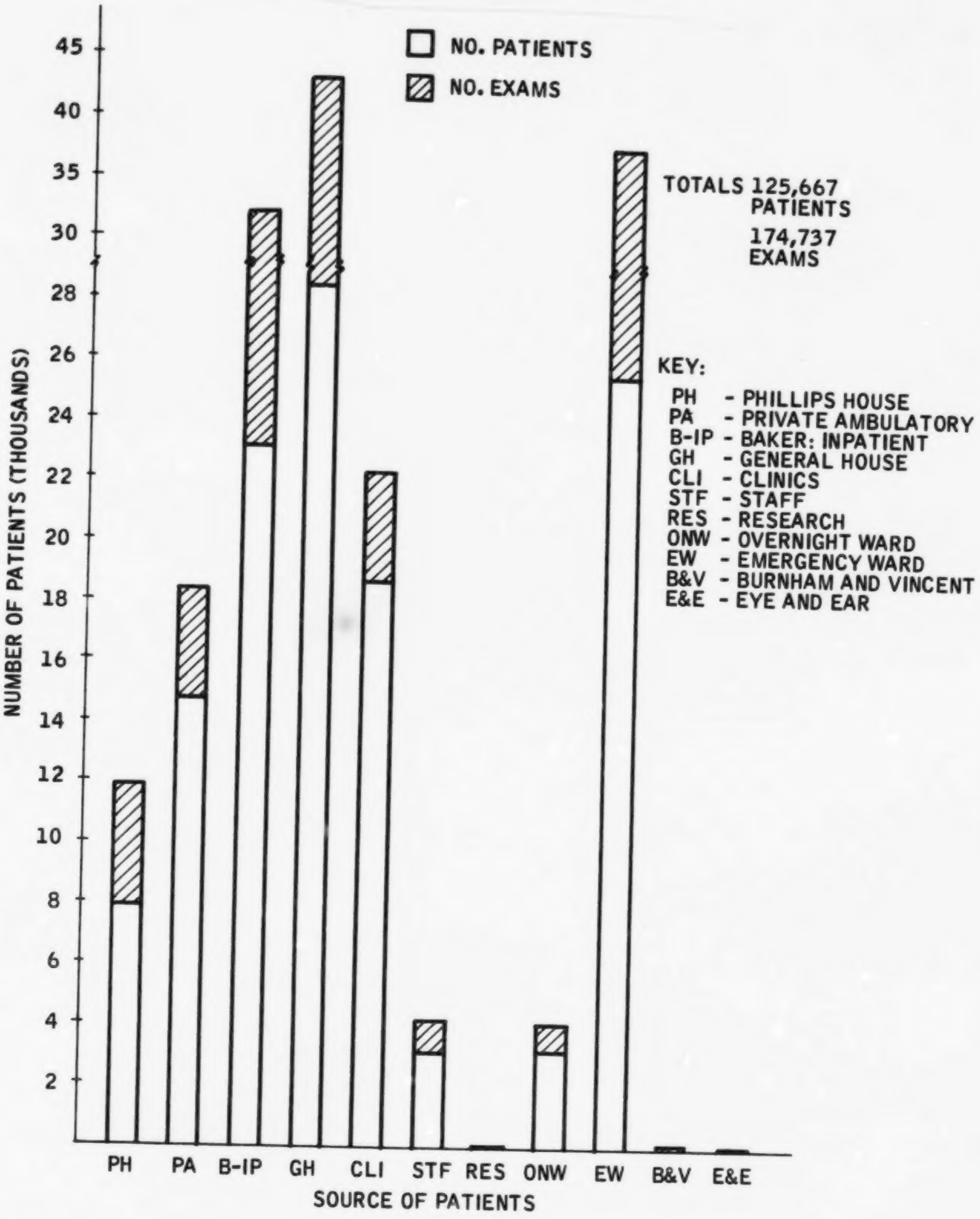


Figure D3. Origins of Patients and Examinations in MHG Radiology -- 1967-68

D5 pLN

Table D2. Number of Patients or Examinations in MGH Radiology by Source of Patients - 1967-68

Source	No. of Patients	No. of Examinations
Phillips House (PH)	7, 927	11, 892
Private Ambulatory (B1)	14, 865	18, 432
Baker: Inpatient (B2)	23, 125	32, 790
General House (GH)	28, 452	43, 348
Clinics (CLI)	18, 702	22, 374
Staff (STF)	3, 793	4, 224
Research (RES)	2	2
Overnight Ward (ONW)	3, 187	4, 086
Emergency Ward (EW)	25, 481	37, 447
Burnham and Vincent (B&V)	115	115
Eye and Ear (E&E)	18	27
Totals	125, 667	174, 737

Fig D4   1[illegible]

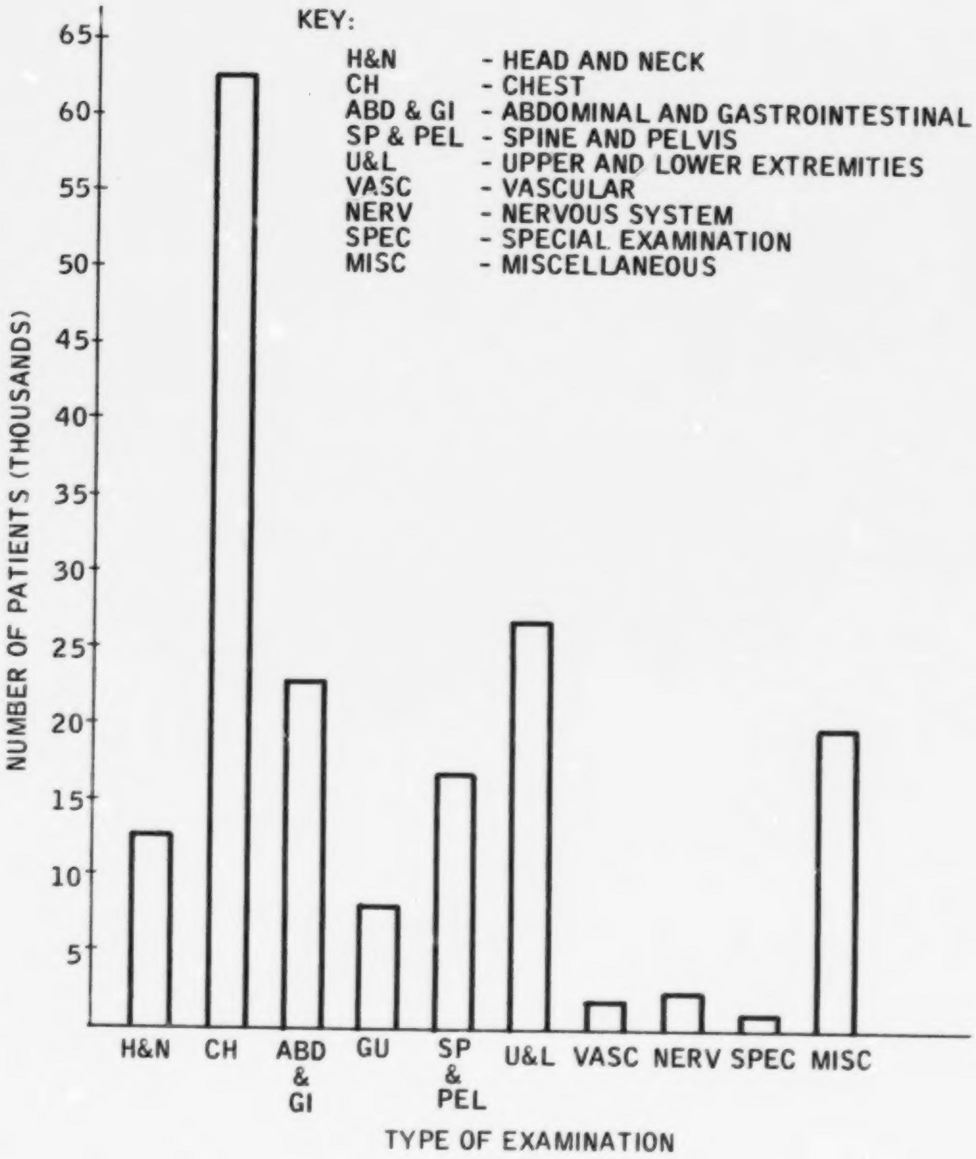


Figure D4. Number of Patients by Type of Examination in MHG Radiology -- 1967-68

Table D3. Number of Patients by Examination Type in MGH Radiology - 1967-68

Examination Type	No. of Patients
Head and Neck	12, 655
Chest	62, 855
Abdominal and Gastrointestinal	22, 666
Genitourinary	8, 033
Spine and Pelvis	16, 879
Upper and Lower Extremetries	26, 832
Vascular	1, 794
Nerve	2, 218
Special Examinations	1, 007
Miscellaneous	19, 798
Total	174, 737

F, D5

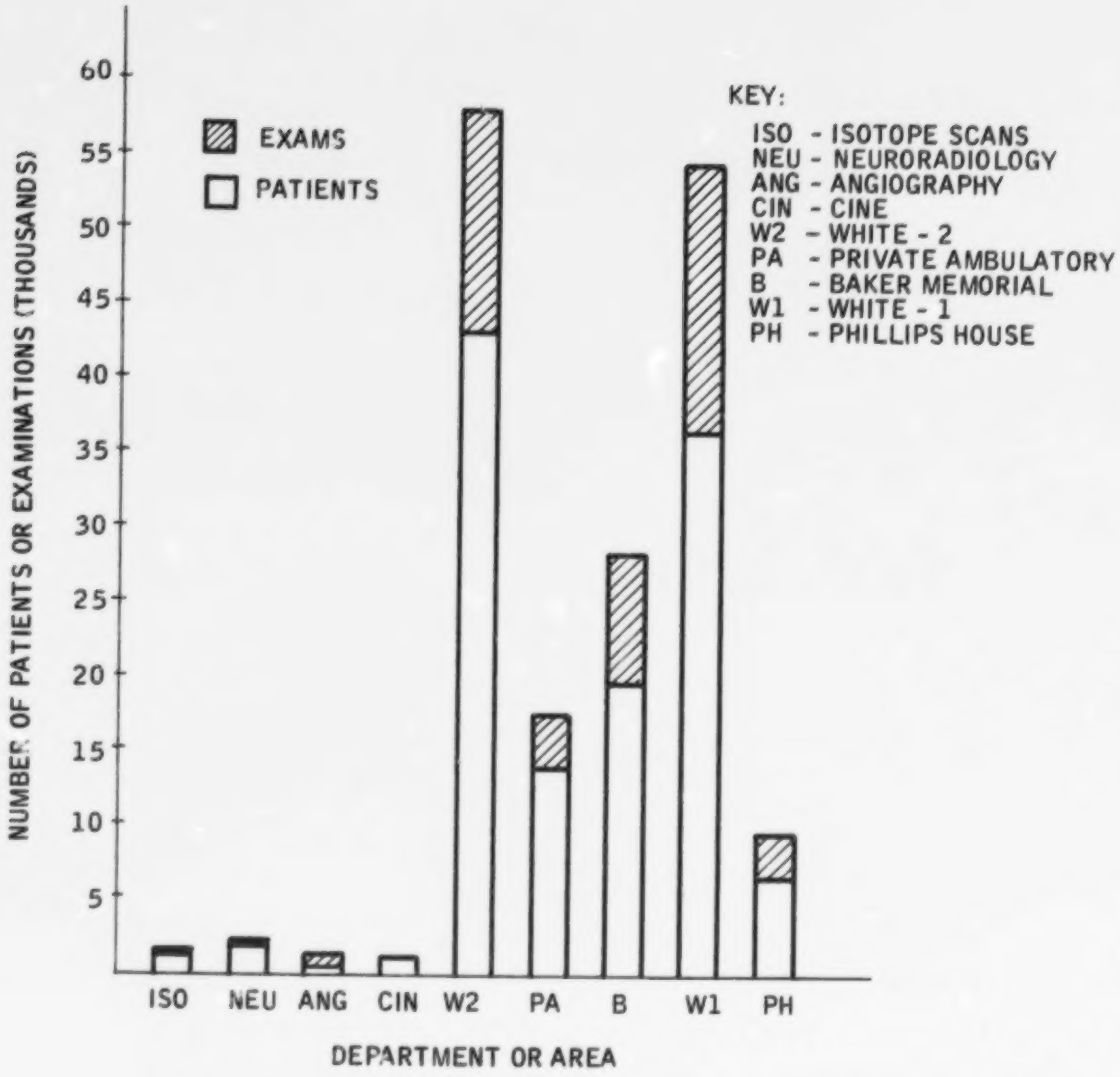


Figure D5. Number of Patients and Examinations Through Each of the Five Radiology Departments plus Subspecialty Areas at MHG -- 1967-68

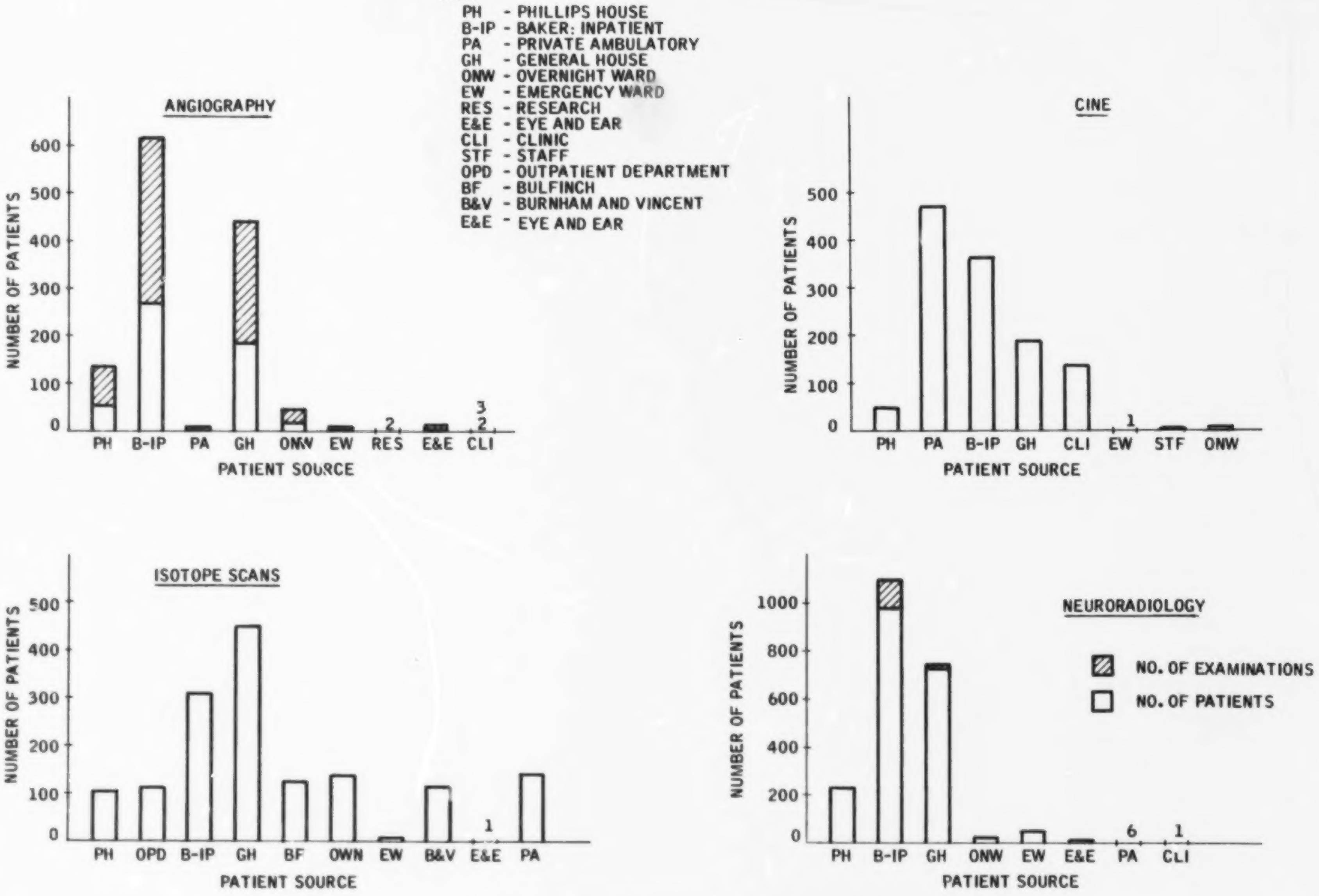


Figure D6. Number of Patients and Examinations in MHG Subspecialty Radiology by Source of Patient -- 1967-68

Fig D7

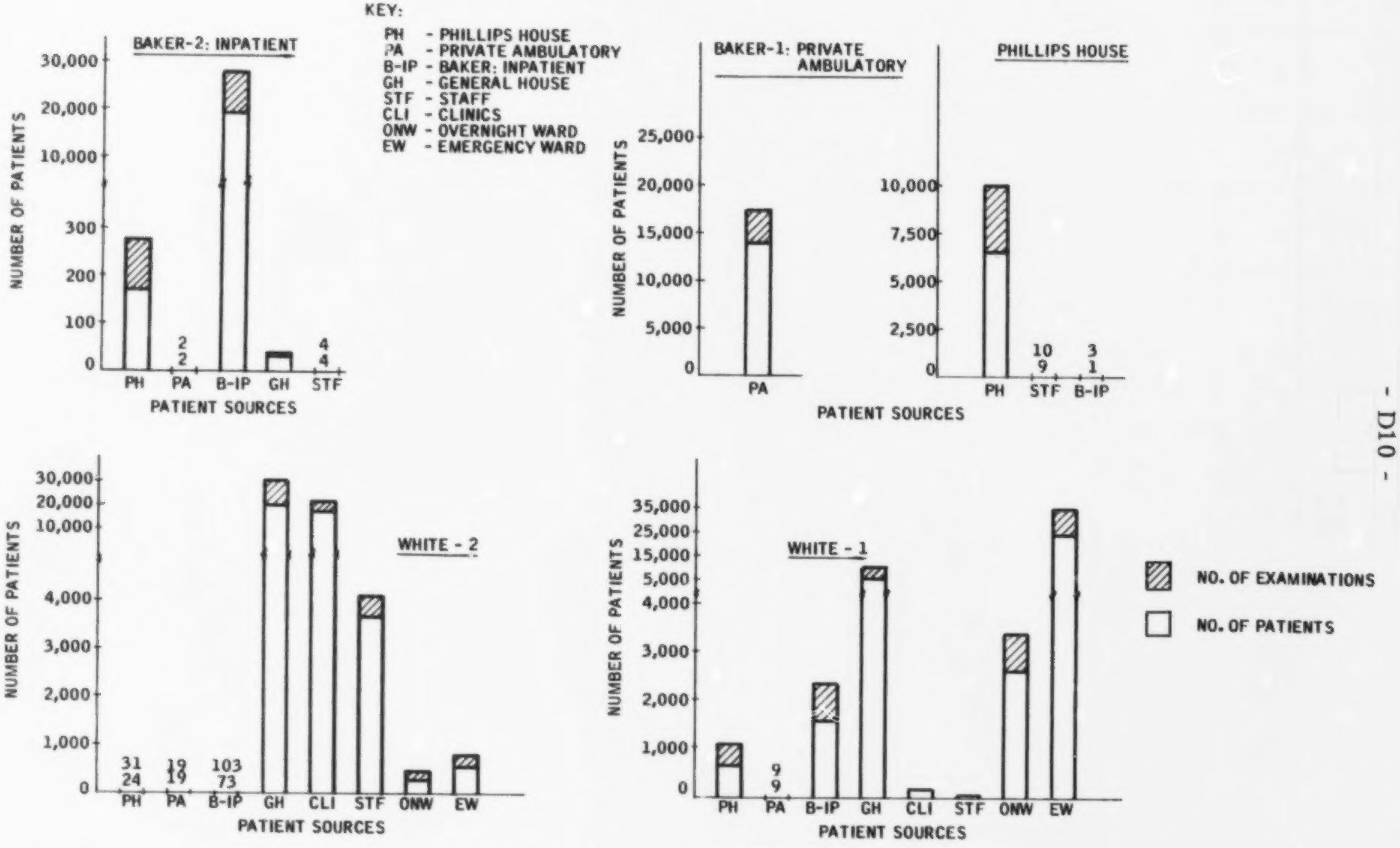


Figure D7. Origin of Patients and Examinations Through Each of the Five MGH Radiology Departments -- 1967-68

Table D4. Most Frequent Patient Sources for White-2 Radiology (Examinations covered: GU, Chest, GI, GB, Bones)

Source	Percent of Total Patients
Inpatients	
White-7	22
White-10	19
White-6	17
White-11	7
Burnham-2	5
Vincent-2	5
Burnham-6	4
Outpatients	
Staff Clinic	17
Fracture Clinic	10
Med. C. Clinic	10
Adm. Phys.	7
Surgical Clinic	7
Ortho Clinic	6

Table D5. Most Frequent Patient Sources for Baker-2 Radiology - Inpatients (All examination types covered)

Source	Percent of Total Patients
Baker-6	10
Baker-9	9
White-8	8
Baker-3	8
Baker-5	7
Baker-12	7
Baker-10	6

APPENDIX E
PATIENT WAITING TIMES - WHITE-2 RADIOLOGY

APPENDIX E

PATIENT WAITING TIMES - WHITE-2 RADIOLOGY

Total patient waiting times as shown in Table E 1 were determined from the dispatcher's signout book. Times used were the dispatcher's recorded arrival time in the department with the patient (pre-examination) and his departure time with the patient (post-examination).

Average posted examination times (Table E 2) are averages compiled from data recorded by the technologists in the X-ray rooms on White 2.

The data was taken on patients examined between the dates of 13 January 1969 and 24 January 1969.

Table E1. Patient Waiting Times

Examination and Code	Total Patient Time Within White-2 Radiology	Number of Patients (N_1)* Requiring this Total Time	Patient Waiting Times	Average Posted Examination Time
Chest PA and Lateral (201)	15 minutes	2	9 minutes	6 minutes
	20 minutes	4	14 minutes	
	25 minutes	1	19 minutes	
	30 minutes	3	24 minutes	
	55 minutes	1	49 minutes	
	1 hour 5 minutes	1	59 minutes	
	1 hour 15 minutes	1	1 hour 9 minutes	
	1 hour 20 minutes	1	1 hour 14 minutes	
	1 hour 40 minutes	2	1 hour 34 minutes	
	2 hours 0 minutes	1	1 hour 54 minutes	
	2 hours 5 minutes	1 N_1 = 18	1 hour 59 minutes	
KUB + Upright (303)	10 minutes	1	2 minutes	9 minutes
	15 minutes	1	7 minutes	
	20 minutes	1	12 minutes	
	30 minutes	2	22 minutes	
	50 minutes	1	42 minutes	
	55 minutes	2	47 minutes	
	1 hour 0 minutes	2	52 minutes	
	1 hour 20 minutes	2 N_1 = 12	1 hour 12 minutes	
IVP (401)	1 hour 0 minutes	1	11 minutes	47 minutes
	1 hour 20 minutes	1	31 minutes	
	1 hour 35 minutes	1	46 minutes	
	1 hour 40 minutes	1	51 minutes	
	1 hour 45 minutes	1 N_1 = 5	56 minutes	
GI Series (321)	1 hour 45 minutes	1	1 hour 17 minutes	34 minutes
	3 hours 5 minutes	1 N_1 = 2	2 hours 37 minutes	

*N_1 = Total patient sample

Table E2. Mean Examination Times*

Examination Type	N**	Mean (minutes)
Head and Neck	28	14
Chest	113	6
KUB	55	9
GI (Gastrointestinal)	17	34
IVP (Intravenous Pyelogram)	61	47
Spine, Pelvis, or Hip	58	13
Upper and Lower Extremities	139	7
Be (Barium enema) †	39	56
GB (Gall Bladder) ‡	24	23

* -From posted sheets (W2) and results of increment 4-5 of RRF time data.

** -Number of examination times of each type used to determine mean time.

† -May be done by one radiologist on 3-4 patients simultaneously thus increasing total time for a single examination.

‡ -Represents one day of a possible 2-3 day GB series.

APPENDIX F
AUTOMATIC DATA PROCESSING ACTIVITIES AT MGH

APPENDIX F

AUTOMATIC DATA PROCESSING ACTIVITIES AT MGH

In addition to the use of automatic data processing (ADP) in both hospital and professional accounting, other areas of computer technology application to patient care are being explored at MGH. This work is the primary effort of Hospital Computer Project (HCP), a research and development program within the Laboratory of Computer Science at MGH. The goals of the HCP are: (1) to develop an understanding of the nature of the problem of improvement of patient care through the application of computer technology and to explore the potential of alternate solutions, (2) to illustrate the technical feasibility of computer applications through small-scale experiments, and (3) to demonstrate the utility and practicality of a computer-based hospital information system by implementing modules of the system which operate efficiently in daily service. It is evident that these goals also describe the intent of the present Diagnostic Radiology system study and the logical extension of the study results and recommendations.

Areas which are or have been of primary concern to the HCP include the following:

- Patient census operation
- Chemistry laboratory requests
- Medical history taking
- Medical records
- Diagnostic X-ray reporting
- Outpatient appointment scheduling

PATIENT CENSUS OPERATION

The area of patient census was selected for ADP application because of the importance to multiple hospital functions of knowing exact patient location and because of the need of a census-oriented data base for the development of other hospital computer applications. Information on patient admissions, transfers, and discharges was processed to provide continually updated bed-availability lists for the three divisions of the hospital and to furnish user information on any patient's bed location and medical record number. The project has been transferred to hospital administration personnel who are assuming responsibility for patient census information in addition to their own computer applications.

CHEMISTRY LABORATORY REQUESTS

A computer system for the preparation of chemistry laboratory spinsheets and worksheets was demonstrated for use in 1967. The system, having been integrated into the operating laboratory routine, handles a daily volume of more than 1500 routine test requests, generating worksheets for each test or test grouping at selected time intervals throughout the day. It has (1) demonstrated a significant saving in technician time (up to 11 hours per day), (2) increased legibility and hence reduced a potential source of error, and (3) provided a data base for the reporting of laboratory test results. Plans are to extend the system into the production of daily and summary lab test reports and to implement direct computer connections to autoanalyzers by February of 1970.

MEDICAL HISTORY TAKING

An on-going HCP project involves a patient-computer interaction to obtain patient history information. As a result of a man-machine dialog taking from 30 minutes to an hour, a prose summary in response to a specially designed history questionnaire is generated for the physician. This automated interview procedure promises more effective utilization of the physician's time and ensures a standardized, comprehensive history. Activity in this area is being extended to include:

- Automatic ordering of pertinent laboratory tests as determined by the patient's response to particular questions
- Histories oriented toward a specific complaint, with the attempt to carry out a minimal form of automatic differential diagnosis
- Programs which will collect pertinent historical information on particular disease processes, such as diabetes, etc.

Other areas are also under investigation by the Laboratory of Computer Science. These include capturing of narrative text information in the medical record, patient diagnosis and treatment, computer system and programming development, outpatient appointment scheduling, and diagnostic X-ray interpretation. The latter two projects are of particular interest in view of the application possibilities to the radiology system development effort and deserve further comment.

DIAGNOSTIC X-RAY REPORTING

The time required to generate edited copy of diagnostic X-ray interpretations has been a continuing concern of practicing radiologists and those physicians requiring diagnostic X-ray information. Long delays are often encountered between the time an X-ray is read by a radiologist and the time the report reaches the physician. Much of this delay stems from the transcription, typing, checking, filing, and transporting procedures required in the current system of radiological reporting. As a result, a MGH staff radiologist, a staff physician, a computer scientist and auxiliary personnel are investigating each area of radiological reporting and developing techniques for entering information into a computer through a combination of a structured vocabulary and free-text input via alphanumeric keyboard. Interaction between radiologist and computer allows the immediate display and recording of X-ray type, anatomical location, pathological findings, and the diagnostic impression. A narrative output is produced by the computer system for direct transmission to the required terminal points. The system has been demonstrated within the laboratory and is now being installed for evaluation on a pilot basis in one of the radiological areas.

OUTPATIENT APPOINTMENT SCHEDULING

Another area of automatic data processing that holds promise of wide applicability is that of patient scheduling. The HCP has conducted several studies to document the characteristics of, and the need for, change in the current outpatient scheduling system. Their recommendation is to provide ambulatory patients with individual appointments for assigned physicians and for other scheduled services through the use of a computer-based scheduling system. Resulting benefits would include (1) improved ambulatory services with a major reduction in patient waiting time, (2) more optimum patient loads for physicians, (3) more effective administrative control of personnel resource allocation, and (4) additional statistical information on patient and clinic operation. An HCP proposal for the implementation of a computer-based appointment system has been favorably received by MGH administration and will be gradually implemented over the next several years.

LABORATORY OF COMPUTER SCIENCES: FACILITIES AND PERSONNEL

The staff of the Computer Sciences Laboratory is composed of a group of dedicated physicians under the leadership of G. Octo Barnett, MD, director of the laboratory, each of whom is concerned with one or more of the projects described above.

The laboratory has its own programming and engineering group and has under its control:

- Duplicate Digital Equipment Corporation (DEC) PDP-9 computer processors
- A DEC PDP-7 processor

The PDP-9 system is characterized as a special-purpose, time-sharing system for use with high-level interpretative programming language. The system can be used in a multiterminal, on-line information system. Its duplicative nature is required because of the primary importance of high reliability when operating in the hospital environement. This system is presently being used as a part of the chemistry laboratory system as well as in the pursuit of various other projects described above. The PDP-7 is a medium-size, non-time-sharing machine with 8K of core memory and secondary disk memory. It has been used in a number of pilot programs, one of which is the diagnostic X-ray reporting study. In reporting work it is used in conjunction with (1) an alphanumberic display scope and keyboard input (Raytheon DIDS-400) and (2) a teletype printer. Other pieces of supporting equipment available to the staff include keyboard tape punch units, light-pen displays (e. g., Fairchild X-Y Indicator, type 737-A), additional Raytheon CRT display units, and printers.

COMPUTER-BASED MEDICAL RECORDS SYSTEM

Another important area of ADP activity at MGH is one involving the computerization of a portion of the hospital medical records library. This program has been under development since 1966 and is being carried out under the direction of the MGH Hospital Administration section, as distinct from the Laboratory of Computer Sciences group. The system is being designed to store and to furnish on demand certain portions of the patient's medical record, a part of which is the data included in the patient's discharge summary, shown in Figure F1. Indication of the need for such a system is evidenced by the following:

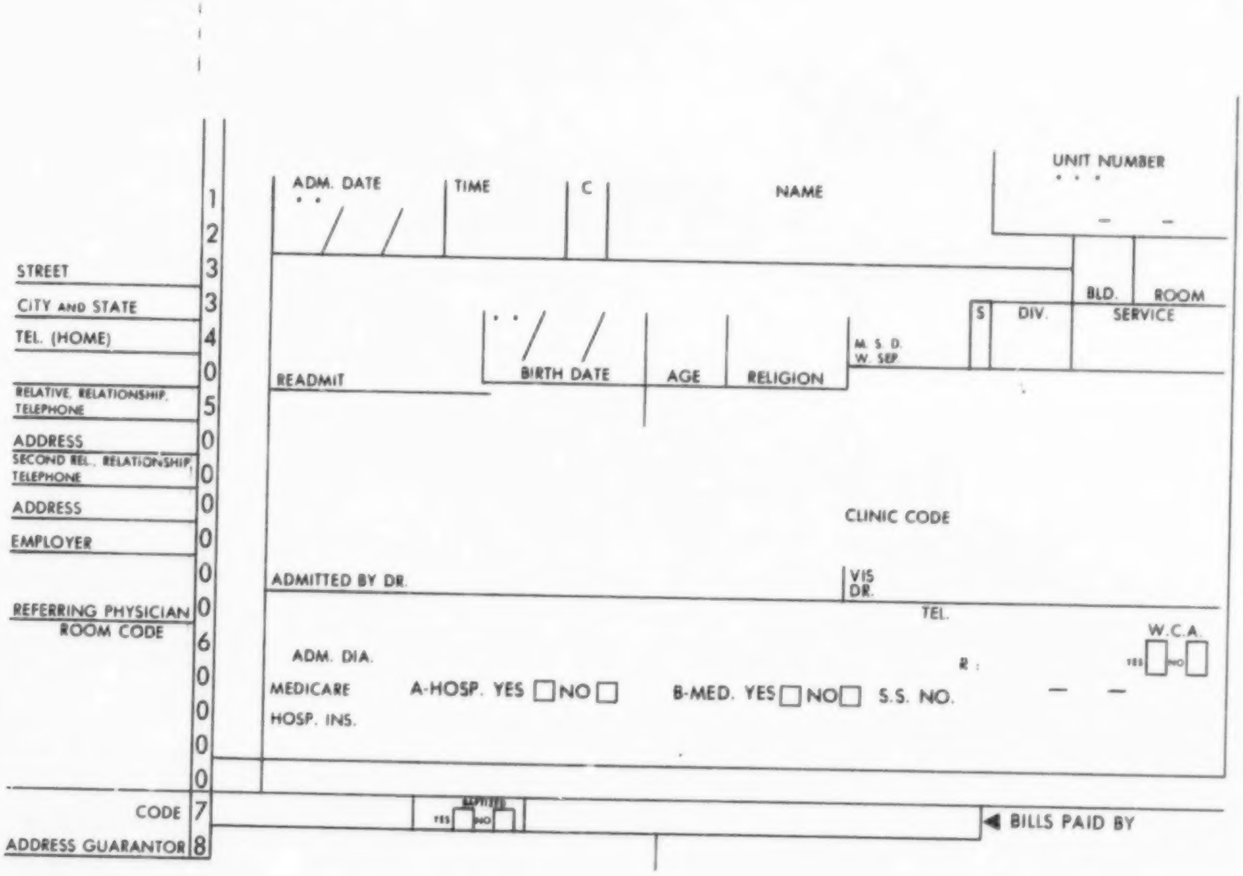
- The hospital presently has to keep track of approximately 1.4 million patient records.
- It has approximately 200,000 to 300,000 active records, i.e. patients within the last three years.
- It has to entertain approximately 2,400 requests for medical record data per day.

Operation of the system will rely upon a complex of computing and ancillary equipment, comprised primarily of the following:

- An IBM 360/40 central processing unit with 128K of memory (193K optional)
- IBM 2314 mass storage device capable of handling 255.5 x 10^6 bytes of information
- Five 2311 disc drives (7.5 million bytes each)

- Four 2401 tape drives (90 KHz)
- Nineteen Sanders 720 terminal display scopes, incorporating 1024- and 512-character memory modules
- Fifteen 35 KSR teletype units

System implementation and checkout should be completed, and the system ready for on-line use, by the end of 1969. The significance of its development can be appreciated when considering its potential use as an integral part of a diagnostic radiology ADP system.



1
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CITY AND STATE 3
TEL. (HOME) 4
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RELATIVE, RELATIONSHIP, TELEPHONE 5
ADDRESS 0
SECOND REL., RELATIONSHIP, TELEPHONE 0
ADDRESS 0
EMPLOYER 0
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REFERRING PHYSICIAN 0
ROOM CODE 6
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CODE 7
ADDRESS GUARANTOR 8

ADM. DATE
TIME
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SERVICE
READMIT
BIRTH DATE
AGE
RELIGION
M. S. D. W. SEP.
CLINIC CODE
ADMITTED BY DR.
VIS DR.
TEL.
W.C.A. YES ☐ NO ☐
ADM. DIA.
R:
MEDICARE A-HOSP. YES ☐ NO ☐ B-MED. YES ☐ NO ☐ S.S. NO.
HOSP. INS.
BAPTIZED YES ☐ NO ☐
◀ BILLS PAID BY

Figure F1. Medical Record Data

APPENDIX G

RADIOLOGICAL REQUEST FORM (RRF) TIME STUDY RESULTS

APPENDIX G

RADIOLOGICAL REQUEST FORM (RRF) TIME STUDY RESULTS

The various time delays encountered in moving the RRF through the system are shown in Figures G1 and G2 and Table G1. In analyzing the steps involved, a few individual cases were seen to be highly atypical, requiring an inordinate amount of time between particular successive increments. If these cases are eliminated, the resulting data can be seen in the summary Table G1 and in the cross-hatched sections of Figure G2. For example, the value for increments 1 through 10 then drops from 2-2/3 to 1-1/2 days on Baker, and from 1-3/4 to 1-1/4 and 2/3 days on W7-10 and W-Clin respectively. A closer analysis would be needed to determine the factors accounting for the deviant cases in the samples.

The time span during which the data was taken was 1 May 1969 through 15 June 1969.

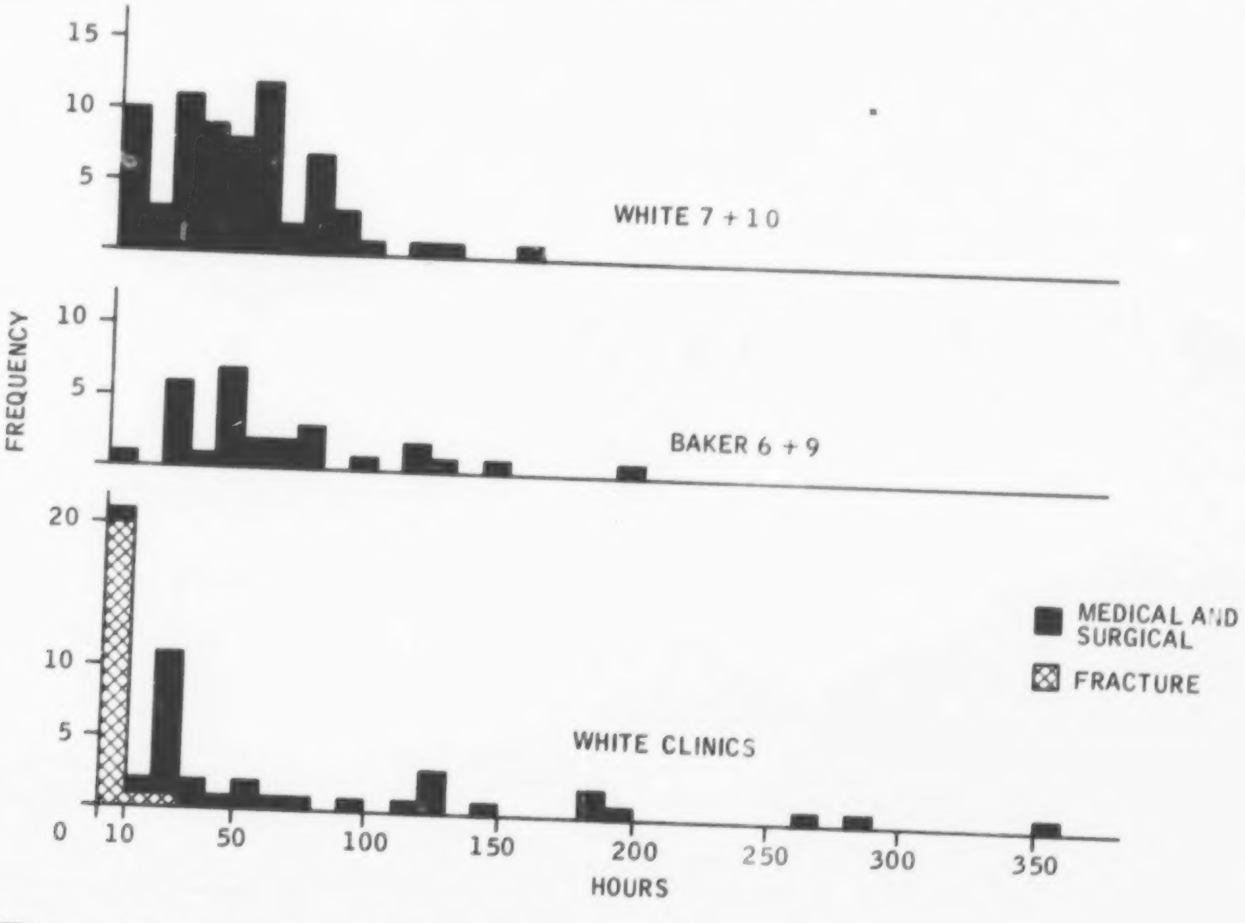

Figure G1. Number of Hours Taken for RRF Increments 1 through 10

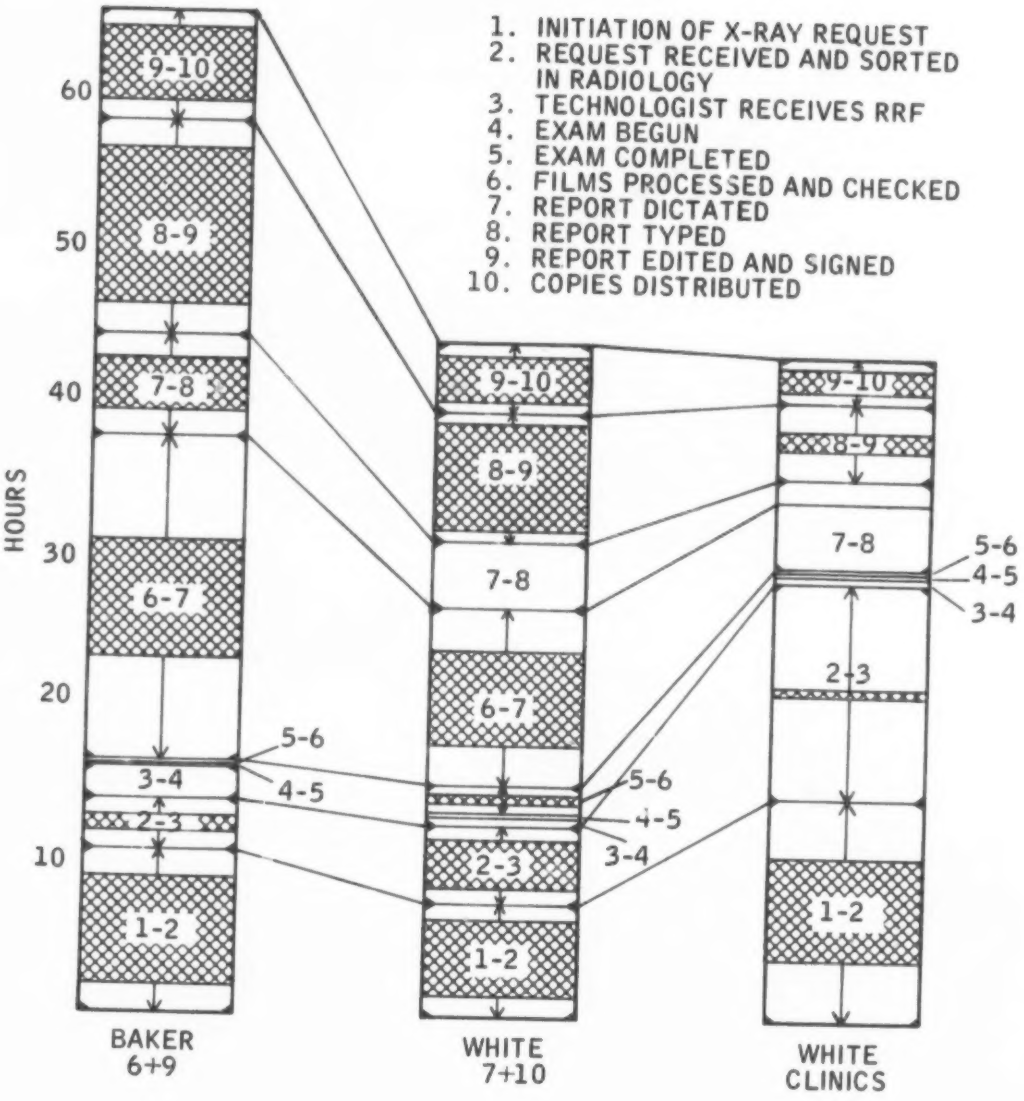

Figure G2. MGH X-ray Time Study

Table G1. RRF Time Delays (to nearest 5 minutes)

Baker 6 and 9					
Increment	Time	N*	Adjusted Time	ΔN**	ΔTime
1-2	10:15	18	6:45	1	3:30
2-3	3:30	16	1:10	2	2:20
3-4	1:55	15	1:55	--	--
4-5	0:10	19	0:10	--	--
5-6	0:10	15	0:10	--	--
6-7	21:10	15	7:30	2	13:40
7-8	6:30	20	3:20	2	3:10
8-9	13:50	17	9:45	2	4:05
9-10	6:55	19	4:40	1	2:15
	Σ 64:30		Σ 35:25		ΔΣ29:05

White 7 and 10					
Increment	Time	N	Adjusted Time	ΔN	ΔTime
1-2	7:15	35	4:55	2	2:20
2-3	5:00	28	3:25	1	1:35
3-4	0:25	46	0:25	--	--
4-5	0:15	60	0:15	--	--
5-6	1:50	49	0:30	3	1:20
6-7	11:25	47	5:55	4	5:30
7-8	4:20	60	4:20	--	--
8-9	8:20	61	6:50	2	1:30
9-10	4:25	64	3:00	3	1:25
	Σ 43:15		Σ 29:35		ΔΣ 13:40

White - Clinics					
Increment	Time	N	Adjusted Time	ΔN	ΔTime
1-2	14:10	48	6:20	4	7:50
2-3	14:05	25	0:25	5	13:40
3-4	0:15	43	0:15	--	--
4-5	0:15	50	0:15	--	--
5-6	0:20	46	0:20	--	--
6-7	4:20	45	4:20	--	--
7-8	1:35	41	1:35	--	--
8-9	4:50	41	1:05	7	3:45
9-10	3:00	46	1:20	4	1:40
	Σ 42:50		Σ 15:55		ΔΣ26:55

* N = Number of patients included in the time-increment sample

**ΔN = Number of eliminated atypical cases

APPENDIX H
TOTAL SYSTEM ALTERNATIVES

APPENDIX H
TOTAL SYSTEM ALTERNATIVES

LC (LEAST-COMPLEXITY) SYSTEM

System Features

The LC system is one which departs least from the manual methods presently used in MGH Diagnostic Radiology in performing the scheduling, film filing and retrieval, and reporting functions. It requires a minimum of computing hardware, peripheral and terminal equipment, software development and personnel training, and as such it represents a "least-cost" system. At the same time, however, the flexibility of the system in providing department management data and a broad base of patient data for research and teaching is correspondingly limited. In addition the BRH requirements for patient and X-ray procedure data can only partially be met.

The heart of the system is a small satellite computer capable of communicating with the MGH Medical Records System central processing unit and dedicated to Radiology department use only. It will perform on-line functions associated with the three major steps in the radiological process of scheduling, old film retrieval, and diagnostic reporting. Its key performance features are:

- Organization of inpatient and active (current) clinic patient descriptor data in a radiology-dedicated computer file
- Automatic scheduling of standard X-ray examinations
- Dispatch area notification of inpatient examination times.
- Film-file area notification of pending examinations, organized to minimize file folder retrieval time
- Conventional free-verse dictation-remote transcription of diagnostic reports
- Provision of patient data for report formatting purposes
- Instantaneous transmission, upon final edit, of the diagnostic report to designated terminal areas
- Permanent computer file record for each patient of basic patient data with date, code, and type of last examination

Operational Description

The LC system is best illustrated by describing its use in the patient examination process.

Scheduling Functions -- The attending physician on the patient's floor decides an X-ray is necessary. He indicates the name of the patient and his room number, in addition to the type of X-ray required, to the unit coordinator (UC), floor nurse, etc. The UC calls the scheduler in the appropriate radiology service and gives the following data:

Patient name
Patient location
Patient unit number
Examination type by code number and date requested
Patient condition (three categories of mobility)

The scheduler inputs patient unit number, examination type and date requested, and patient condition at the scheduling terminal. (The terminal must have alphanumeric input, display, and edit capability.) As the scheduler inputs data, it is instantly displayed to ensure correctness. Upon verification, the data is transmitted to the computer. The computer then assigns an examination time and location (examination room) for the particular patient and notes any dietary restrictions associated with the requested examination. The patient assignment is based upon the following:

- Rooms available and the X-ray procedures they are capable of handling
- Average times required to perform the requested examinations for patients in the three mobility categories
- Time spans within which rooms can be used (e.g. 8:00 a.m. 5:00 p.m.)

The information displayed to the scheduler is:

Patient name
Patient unit number
Patient location
Examination type and code
Patient condition
Examination time, date and room
Dietary restrictions

The system has thus correlated examination type, code, and dietary restrictions; patient name and unit number; and has assigned a date, time and examination room to the patient in question. It will also place this patient data in an active-hold computer file, to be made use of in film retrieval and reporting procedures. This series of events, occurring between input and display will require no more than 5 seconds of elapsed time.

The examination time and location is then conveyed to and approved by the unit coordinator, verbally, during the course of the original telephone inquiry. Upon approval, the scheduler can have data transmitted to patient's floor, where a hard copy is printed out for insertion into the patient's current record. Dietary instructions are also included in printout at this point.

For the purpose of dispatch notification the computer will periodically scan the roster of scheduled patients and select those whose examinations are scheduled for that time period immediately forthcoming (e.g., the next half hour). Printouts of tearoffs in the dispatch area will contain:

Patient name

Patient unit number

Patient location

Examination time, date, and assigned room

Filing Functions -- Verified schedule information is then transmitted to the central system. The system organizes the information according to actual clock time and scheduled examination time, allowing transmittal of those film file requests to the filing areas which are needed most immediately. Within each computer-organized time increment, patients are ordered according to the terminal digits of their unit number and the date of the last examination to facilitate film file retrieval. The ordering required will depend upon how the filing area is physically laid out but will be simple to accomplish from the required software standpoint.

Data is then transmitted to the appropriate file area in White-2 or Baker-2, based on the origination point of the patient scheduling information. The data required at the file area is:

Patient name and location

Patient unit number

Examination type and code

Scheduled examination date and time

Date of last examination (when available)

It is presented to the file area at 15-minute intervals, organized as described above. Each patient's data is printed on a separate tearoff section of the hard-copy output to aid in film folder retrieval and subsequent collation. In addition to being printed out, the patient data is also held in a temporary memory for final verification after the examination has been given.

Once the file clerk has the data necessary for folder retrieval, the method of manual retrieval is carried out as indicated in the file function flow diagram. The new films, and the RRF accompanying the new films; the old films, and the printout tearoff collating aid are assembled for transfer to the viewing area. Once the new films have been read, the radiologist (or medical secretary) indicates on the computer scheduling slip that the examination was given, as listed or notes any appropriate changes (examination not given, additional examinations given, examination cancelled, etc.) on the slip. This slip can then be returned to the scheduling terminal area for later batch verification and correction where changes in the scheuled examinations require it.

Diagnostic Reporting Functions -- In the reporting phase of the diagnostic X-ray procedure, the computer will act in a message handling and transmission mode. The radiologist will dictate his diagnosis (message) into a Nyematic dictation system. The message will be directed to a central station where a medical secretary is available for transcribing the report. The report is then typed at a terminal which allows alphanumeric input and immediate display of the typed input for a preliminary edit of typographical errors, etc., by the medical secretary. The only report formatting data required by the secretary is the patient unit number, for this and the remainder of the patient data are already available in the active-hold computer file. Inputting the unit number and activation of a "Request" function key will automatically retrieve the patient data associated with the unit number. This data will be displayed for the purpose of verifying it with the dictated patient information. Upon verification of the patient identifiers, the secretary then completes the remainder of the report, exercising her edit capability through the use of a rapid cursor associated with the CRT display.

With the completion of the report, the secretary will activate a "Transmit the Final Edit" key to relay the complete report text to the radiologists' viewing area. Since the radiologist must have the capability for final review and approval, a terminal with display and alphanumeric input features must be located in the viewing area. Upon review and final edit, the radiologist inputs his identification code, which is in turn displayed for verification. Activation of a "Report OK" function key will cause automatic transmission of the signed report to the following areas:

- Film filing
- Professional billing offices
- Hospital billing and accounting
- Central message - dispatch center, where remaining copies are disbursed as required

HC (HIGH-COMPLEXITY) SYSTEM

System Features

The HC system represents an assembly of subsystem alternatives which will afford the greatest degree of automatic information handling within MGH Radiology. At the same time, it requires a heavier commitment in the areas of computing hardware, peripheral and terminal equipment, and software development. Terminal equipment characteristics have been suggested for the scheduling and film filing functions with the aim of minimizing equipment cost and personnel training and of selecting personnel procedures which represent a "natural way of doing things".

The system again relies on a satellite computer dedicated to Radiology Department use only and tied to the Hospital Medical Records System for periodic two-way information and data transfer. The satellite system will, of necessity, possess greater capability in handling and storing patient data, and information relating to scheduling, filing, and reporting subsystem functions. Data transfers from the Medical Records System will be concerned with currently active inpatients and clinic patients and will thus aid in maintaining an up-to-date and currently useful radiology Patient Index File.

The system will incorporate the following features:

- Organization of inpatient and active (current) clinic patient descriptor data in a radiology-dedicated computer file
- Automatic scheduling of standard X-ray examinations
- Automatic generation of required patient preparation information
- Dispatch area notification of inpatient examination times
- The potential for dynamic updating of a patient's X-ray schedule
- Film-file area notification of pending examinations, organized to minimize file-folder retrieval time
- Automatic channeling of file folder requests to the appropriate file area, based on current folder transferral information
- A convenient method of indicating and tracking file-folder transfers and loan-outs
- A method of rapidly generating edited and approved diagnostic X-ray reports
- Provision of patient data for report formatting purposes

- Instantaneous transmission, upon final edit, of the diagnostic report to designated terminal areas
- Permanent computer file record, for each patient, of basic patient data with date, code, and type of last examination.

The HC system does not include a post-examination X-ray tracking scheme. While this type of system is desirable ideally, it is difficult to justify because of the additional cost and procedural requirements involved. This decision is based upon the fact that only a small percentage (1% or less - possibly as low as 0.3%) of retakes are required because of X-ray loss during this part of the film-handling process.

Operational Description

The HC system is best illustrated by describing its use in the diagnostic X-ray examination process.

Scheduling Functions --

Inpatient Scheduling -- The attending physician on the patient's floor decides an X-ray is necessary. He indicates the name of the patient and his room number, in addition to the type of X-ray required, to the unit coordinator (UC), floor nurse, etc. The UC initiates contact with the Radiology scheduling system to input the following data:

Patient name

Patient location

Patient unit number

Examination type by code number and date requested

Patient mobility category

Requesting physician

Contact with the scheduling system is accomplished through an inexpensive terminal device similar to a Touch-Tone Card Dialer phone terminal. It should incorporate the following features:

- Card reader - The card will contain the patient unit number, eliminating the necessity of manual transcription or repeating (by voice or writing) of the unit number.
- Multiple-key-keyboard - This will provide numeric input and the allowance for special function keys (a 12- to 16-key matrix).

- Telephone connect with the X-ray scheduling subsystem.
- Audio response from the computer scheduling subsystem.

The UC, etc. would dial the appropriate Radiology scheduling code for connection to the vocal scheduling sequence. In response to system (computer)-generated queries, the following patient data would be input via the card reader and keyboard:

Input	Means	Response
Patient unit no.	Card or keyboard	Audio verification
Patient location	Keyboard	Audio response
Examination type	Keyboard (examination code)	English-equivalent of examination code
Date requested	Keyboard	Audio response
Patient mobility	Keyboard	Audio response
Requesting physician	Keyboard (physician code)	Audio response

Upon verification, the data is transmitted to the computer. The computer then assigns an examination time and location (examination room) for the particular patient and notes any dietary restrictions associated with the requested examination. The patient assignment is based upon the following:

- Rooms available and the X-ray procedures they are capable of handling
- Average times required to perform the requested examinations for patients in the three mobility categories
- Time spans within which rooms can be used (e.g., 8:00 a.m. - 5:00 p.m.)

Audio response for transmission of the scheduling information will be

Time and date of examination

Location (within radiology)

Diet restrictions and/or patient preparation

The required patient preparation data which is presented is based upon the type of examination required and the time for which it is scheduled. It can be presented in verse or code form, as follows (presentation in code form would minimize the demands on the computer-generated audio response vocabulary):

0 - X-ray (no prep required)

1 - Cleansing enema at bedtime

2 - Cleansing enema in morning

3 - Light supper night before

.

.

etc.

Hard copy of this scheduling data can be provided by conventional transcription by nursing station personnel, or the verbal data can be recorded onto magnetic tape during the input-response process, to be typed and inserted into the patient's current floor record by the local medical secretary. The allocated time slot, patient unit number, examination code, and scheduled examination room would be transferred to the current computer-recorded examination schedule, which is accessible for review by the central schedulers within radiology. Stat X-ray requests would be taken care of through the central radiology schedulers by means of conventional phone contact by nursing station personnel. The scheduler would, in this case, select one of the emergency time slots held open in the day's schedule (i.e., programmed into the scheduling system) to accommodate stat requests. This is presently done on an "informal" basis in the manual scheduling process.

The system has thus correlated examination type, code, and dietary restrictions, patient name and unit number, and has assigned a date, time and examination room to the patient in question. It will also place this patient data in an active-hold computer file, to be made use of in film retrieval and reporting procedures.

For this purpose of dispatch notification, the computer will periodically scan the roster of scheduled patients and select those whose examinations are scheduled for that time period immediately upcoming (e.g., the next half hour). Printout of tearoffs in the dispatch area will contain:

Patient name

Patient unit number

Patient location

Examination time, date, and assigned room

Incorporation of a dynamic updating function will require that the scheduling system be notified upon completion of the examination of the patient within the radiology area. The notification function can be performed by either dispatch or scheduling personnel in the radiology service area. It will require the use of a card identifier which would accompany the patient to the examination area. Upon completion of the X-ray examination, the card is inserted in a card reader which is dedicated for use in a schedule update mode only. The computer system receives the patient unit number, notes the real-clock time, and compares it with the patient's scheduled examination time, to which the appropriate examination time increment has been added. A comparison is therefore provided of the patient's scheduled "time out" with the actual "time-out" and is used to compute ± delays for patients to be examined later in the day. The accumulated delays and their effect on patients subsequently scheduled can be displayed at the nursing stations, for example, on a central television monitor similar to those found in large airport terminals. The same type of display can be used in the dispatch area within radiology to regulate the activities of the dispatch personnel.

Although the incorporation of dynamic updating into the inpatient scheduling process is not necessary for the operation of the above described scheduling procedure, it will allow the following:

- A continuing comparison of a patient's scheduled time with the actual time he will be examined. This comparison is based upon any accumulated time delay increments caused by longer-than-scheduled examination times for patients who precede the patient in question.
- A display of accumulated delay times at the nursing stations in question, allowing optional rescheduling by floor personnel.
- Notification to the dispatch area of schedule delays, allowing more efficient and timely use of dispatch personnel.

Outpatient Scheduling -- Candidate outpatient scheduling procedures exhibit many of the same basic characteristics as those outlined in the discussion of inpatient scheduling methods. The differences which arise are those due to the nature of the typical outpatient:

- He is more mobile.
- He is not residing within the hospital.
- His need for treatment is generally not as urgent as that of the inpatient.

Because of these differences scheduling procedures will vary somewhat from the inpatient procedures, and these variations will arise from the fact that the patient himself must act to satisfy the schedule requirements.

The required input data for outpatient scheduling from the clinic area is

Patient name
Patient unit number
Patient location (clinic area)
Examination type requested
Examination date and time requested
Patient mobility category
Responsible physician

The manner in which this data is acted upon is identical to that which is described in the inpatient scheduling alternatives, except that the patient is given the scheduled examination time, area, and preparation procedures by the receptionist or nurse who iniates the scheduling procedure in the clinic area. He is expected to act on this information accordingly by following the requested preparation procedures and appearing when and where requested. Since the patient is usually mobile, no dispatch notification is necessary prior to examination time.

The fact that the patient controls his own activities prior to the scheduled examination time lessens the usefulness of dynamic schedule updating and notification of same at the clinic terminal. This function is an aid primarily to floor (nursing) and dispatch personnel in coordinating their activities with the actual X-ray examination schedules of the patients for which they are responsible. If the daily influx of clinic patients contributes to significant queing within the diagnostic radiology area, however, dynamic updating and notification of the terminal (clinic) area would aid in regulating the flow of clinic patients into radiology.

X-Ray Film File and Retrieval Functions --

File Area Notification -- The information acted upon for film file use is the patient data which has been input to the system in the scheduling process.

The system then organizes the patient schedule information according to actual clock time and scheduled examination time, allowing transmittal of those film file requests which are needed most immediately to the filing areas. Within each computer-organized time increment, patients are ordered according to the terminal digits of their unit number and the date of the last examination to facilitate film file retrieval. The ordering required will depend upon how the filing area is physically laid out but will be simple to accomplish from the required software standpoint.

Data is then transmitted to the appropriate file area in White-2 or Baker-2 based on the origination point of the patient scheduling information. The data required at the file area is:

Patient name and location

Patient unit number

Scheduled examination date and time

Examination type and code

Date of last examination

File area location (based upon date of last examination and/or last file folder transferral data)

It is presented to the file area at 15-minute intervals, organized as described above. Each patient's data is printed on a separate tear-off section of the hard-copy output to aid in film folder retrieval and subsequent collation. In addition to being printed out, the patient data is also held in a temporary memory for final verification after the examination has been given.

Operation of this system depends upon the existence of a computer patient index file (PIF). This file would include, for each patient, the date and type of the last examination in addition to other patient data necessary to the technical and administrative aspects of the diagnostic X-ray process. It would ultimately replace the Kardex and stand-up files which now exist in the White-2 and Baker-2 file areas, respectively.

Prior to the printing out of the scheduled patient data within the file area, the PIF would automatically be interrogated as to file area location based upon the data of the last examination and/or the latest file folder transferral data which has been input to the system (discussed below).

Should the indicated file area location differ from the central active file area, this same information (except for the presently-requested examination data) would also be routed to and printed out in the appropriate indicated file area.

An example of this procedure would be the presentation of request data within the proposed active file area for the MGH Gray Building. All White in-and outpatient file requests would be presented at this point in hard-copy form, as described above. If, during the process of automatic interrogation of the PIF, there is an indication that the file folder resides in the Gray Building sub-basement file area, the data would be immediately transmitted to the sub-basement where it would be printed out for use in retrieval and transportation by dispatcher to the active file area.

Film Folder Loan and Transferral -- Although the filing subsystem outlined above can be used as it stands, it will depend solely upon the date of the last examination for specifying file area location of patient's folders. This requires that tight management control must be maintained over film folder librarying procedures, and that folders be shifted from active to semi-active file areas in precise accordance with last-examination dates and folder rotation time period requirements (e.g., from the 6-week active file to the 6-week-5-year semi-active file area, as in the proposed White-2 filing system layout). It also means that presently-used manual transcribing procedures be employed to indicate the loan-out or transfer of file folders outside of the file areas for uses other than current patient X-ray interpretations. Incorporation of a method of folder location would lighten these requirements. The use of a semi-automated "log-in, log-out" procedure will provide a rapid method of more definitely pinpointing the location of a patient's folder.

The logging procedures will require the establishment of central log-in points in both the Baker-2 and White-2 or Gray Building (active-file) areas. All requests for film loans and file area transfers of folders will be channeled through these two points. The system will utilize the PIF, to which the more detailed information on file folder location will be added. Upon the request of a clinician for the loan of certain films on a patient, the file clerk will either interrogate the patient index file to determine the folder location or initiate her search on the basis of data furnished her by the requestor. Upon retrieval of the folder, she would then notify the computer system of the impending loan transaction by inputting the patient unit number at an appropriately configured terminal in the file area. The system would verify the basic patient data, to which the file clerk would add "DATE", "TRANSFERRED FROM (AREA)", "TRANSFERRED TO (AREA)" and the films-loaned information. File area, ward or clinic areas, or outside-hospital transfers would be denoted by abbreviation or code. Logging-in procedures for returning film loans would follow an identical, but reversed, procedure.

This type of film file logging system is similar in many ways to one which is in pilot operation in the Radiology Department at Johns Hopkins Hospital, Baltimore, Maryland. (Reference 20). Although the system has demonstrated its usefulness in X-ray film librarying and control, certain practical shortcomings have been revealed in the mechanics of logging films in and out of the file areas. Primary among these is the necessity for keyboard entry by file personnel of the patient unit number in the process of querying the film library computer file associated with the system. It is evident, however, that this sort of drawback need not remain as one. With the recent explosion in the development of various types of terminal (I/O) hardware, it is a near certainty that an appropriate terminal for this function will become available soon or could be developed at a nominal cost.

A type of terminal already in existence is that described in the discussion of scheduling; it also has application in file-folder logging. This system is especially suitable for the file transfer application, where access to, or entrance of, frequently changing data is necessary. In file-folder loan-out (for current examination or loan), the following terminal characteristics and usage will satisfy the requirements for loans:

- Card reader, the card containing the patient unit number. The card identifying the patient would be contained in a small pocket on the MEV. Voice response would be capable of repeating patient unit number, if desired.

- Twelve- or sixteen-key input keyboard to input "area transferred from" and "area transferred to" in numeric code. Voice response would give verbal description of these areas, corresponding to the code given. Examples of transferral information are:

From	To
W2	W3
W2	Current Examination
W3	W14

- Provisions for voice response of current date.

- Special function buttons (out of an available 16 to allow transfer of the approved-by-file-personnel, vocally verified data to the Patient Index File. The PIF could at any time be querried from the file area to learn of the current status of the patient's MEV, with the status review either printed out or displayed. This application requires the use of an audio subsystem at the central radiology computer installation. The subsystem accepts requests for information and translates replies from machine-coded data to audible English-language statements. The messages consist of pre-coded words and phrases, sounding exactly as if spoken by live operators. According to one manufacturer's configuration, the vocabulary is recorded on sound film which is optically read, and is not subject to wear.

Diagnostic Report Generation Functions -- The recommended reporting subsystem for use in the HC system is the DITRIDE method, described in subsection 7.4.4 of the main body of this document.

APPENDIX I
TOTAL SYSTEM ALTERNATIVES - TRADEOFF CONSIDERATIONS

APPENDIX I
TOTAL SYSTEM ALTERNATIVES - TRADEOFF CONSIDERATIONS

Before the implementation of a total system configuration within MGH Diagnostic Radiology, several tradeoff considerations must be closely reviewed by hospital personnel. These are

- The ability of the system to satisfy the functional requirements of the diagnostic X-ray process
- The equipment requirements
- Computer software development needs
- Personnel training

The recommended total system resulting from this study has been based primarily on computer hardware and procedural concepts which will satisfy the functional requirements of the department as they have been defined. Thus, the first item above was of paramount importance in the system synthesis phase and continued as such throughout the study.

TOTAL SYSTEM TRADEOFFS

While accurate dollar cost estimates cannot yet be assigned to the various alternatives, generalized equipment requirements can be assigned to each. This is done in Table I1, which gives a listing of the estimated equipment requirements at various stations in the diagnostic X-ray process. The reader will note that the terminal equipment needs of the recommended (REC) system are similar to those of the LC system, with the exception of the film file area where the HC system terminal requirements prevail.

The other major differences between the REC and LC systems lie in the software development, personnel training, and the complexity and capacity of the central computing system.

The actual scheduling functions performed are similar for all three systems, except that for the HC system terminals are used at the nursing stations and clinic points to schedule a majority of the X-ray examinations. Training in the use of the equipment for scheduling purposes would therefore have to include nursing personnel, unit coordinators, etc., as well as those who are acting specifically as "central schedulers" within the Radiology Department. Software development costs are also commensurately larger for the HC system.

Table I1. Estimates of Alternate System Terminal Equipment Requirements

System	Scheduling Functions	Dispatch Functions	Film File Functions	Reporting Functions	Other
LC System	Central Schedulers: Four terminals[*] Alphanumeric input, display, edit (AIDE) capability Emergency Ward: One terminal Alphanumeric input; display, edit capability	Dispatch Area: One printer	Film File Areas: Baker 2: One printer Gray Bldg (second floor): One printer	Nyematic Dictation System (number of handsets required comparable to number of dictaphones currently in active use) Viewing Areas: Nyematic handsets Minimum of seven terminals[†] Display, edit, alphanumeric input Transcribing Area: Minimum of seven terminals (est)	Report Destination Points: File Areas:[‡] One printer each for Baker-2 and Gray Bldg, second floor Professional Billing: One printer Central Message: One printer
HC System	Central Schedulers: Two terminals[**] AIDE capability Nursing Station, Clinic Points: One data input device each point One schedule display each point Dispatch (for schedule update function) One card or tape reader Emergency Ward: Same as LC system	One printer	Film File Areas: Gray 2, Baker 2, and Gray sub-basement; One printer each area One card reader-keyboard each area (minimum) One data display for Gray 2 Baker 2	Same as LC system	Same as LC system
Recommended System	Central Schedulers and Emergency Ward: Same as LC system	One printer	Film File Areas; Same as HC system	Same as LC system	Same as LC system

[*] Appropriate split between Baker and White 2-Baker 1, 2, and PH; 2-White 2

[**] 1-Baker 2, 1-White 2

[†] 1-EW; 3-Baker; 3-White 2. Maximum could approach the number of dictaphones currently in active use.

[‡] Film file function may also be incorporated.

Differences also exist between the HC (and REC) and LC systems in the training and software requirements for the film-file functions. Since the LC system involves simply a notification of the file area personnel of pending examinations, software development is minimal. The only training required is a familiarization of personnel with the equipment located in their areas and brief instruction in the use of the data presented them. The REC system (identical to the HC system in its file functions), however, incorporates a more complicated folder logging procedure for film loans and transferrals, as well as patient index file interrogation, in addition to the notification function. These features will require a more exhaustive indoctrination period for file personnel and training in the use of the correspondingly wider variety of terminal equipment. The scope of the software development encountered here is comparable to that required in the Johns Hopkins study (ref. 20 and 36).

Perhaps the most significant difference between the three systems which is not revealed in Table I1 is the difference in the diagnostic reporting methods. Although the terminal equipment needs are identical, the manner in which the report material will be processed varies considerably. This difference is most evident in the training required of the radiologist, the degree of software development necessary to implement the techniques, and the computation and storage capacity of central processing unit (CPU). The LC system requires that the computer serve only in a message handling and transmission mode. In this sense the demands on the computer system are minimized, and the radiologist is not required to conform to stringent rules imposed by the reporting method. In contrast, the HC system requires that the radiologist structure his verse so that the computer can analyze what he has said for subsequent retrieval purposes. The REC system reduces, but does not eliminate, the need for verse structuring by requiring that only the "Impressions" portion of the report be structured grammatically. This difference will not reduce the training required for the radiologist, but will increase the speed with which he can generate reports using the DITRIDE reporting scheme.

The training required for the use of DITRIDE will apply to both the radiologist and the medical secretaries who will transcribe the reports. It should include a review of basic grammatical rules used in analyzing sentence structure, exposure to sample reports prepared according to these rules, a review of the report format requirements, and actual report dictation where these rules can be applied. Above all, the radiologist must be made aware of the benefits to be derived through the proper use of the method. This will aid in creating the enthusiasm necessary for the successful introduction and use of the structured verse technique.

While the additional training, software development and system capacity will result in a higher total system cost, the benefits resulting from the investment accrue accordingly. The system will provide computer-aided analysis, storage, and transmission of reports; tightly controlled film-file management;

and a more realistic and closely regulated method of patient scheduling. These benefits can be realized through the implementation of the REC system and at a cost which is less than that associated with the HC system alternative.

CENTRAL PROCESSING UNIT (CPU) CONFIGURATION TRADEOFFS

There are basically four choices open to Radiology in the selection of a central processing unit (CPU). These are:

- Make use of the Medical Record System (MRS) on a shared basis.
- Have a satellite computer system capable of communicating with the MRS computer and able to serve the functional requirements of the Radiology system (scheduling, film filing, and reporting).
- Have a stand-alone computer system capable of performing all functions required by the Radiology department.
- Make use of an outside time-sharing vendor by means of data communications equipment.

These four possibilities are analyzed in the following paragraphs. The second possibility is strongly recommended.

Use of the Medical Records System Computer

An important part of planning new activities in any institution is the control of costs. At first glance it would seem that low-cost computer service can be obtained by centralizing all computing services in one large system. Arguments have been made to support this premise, often by computer marketing people selling giant systems, based upon "Grosch's Law", which states that computing power in terms of instructions per second goes up roughly as the square of the cost of the computer system. Unfortunately things seldom work out that way in practice because of Parkinson's law and other less obvious behavorial characteristics of human institutions. These factors have considerably more practical bearing upon the useful quantity and quality of service which a user gets out of a computing system than does Grosch's Law. Hence, we do not believe that this solution would necessarily prove to be the cheapest for the Radiology department, even though we concede that, on the surface, a cost advantage can be shown for this approach at this time in the absence of any operating experience.

This approach is subject to some severe disadvantages. First, the MRS system was planned without the Department of Radiology's needs being kept particularly in mind, with Radiology becoming aware of the design parameters after the fact. The lead time in developing new software and in ordering new hardware is extremely long, and the likelihood is very small that new developments in this system will be responsive to the total needs of the Radiology Department.

Second, the Radiology department would have no autonomy in using the MRS computer. All hardware and software designs and plans would be by interdepartmental committee. The result of such plans can all too frequently be a compromise which makes the system really attractive to nobody, although it in some sense covers everybody. Furthermore, the Radiology department would be unable to experiment conveniently with on-line programs for its own purposes. Experimentation would result in a substantial risk of interfacing with production-type record processing functions which would have to occur as "background" tasks on the MRS computer at all times. It is very hazardous to mix "checked-out" "un-checked out" programs in memory in any computing system, particularly in one which does not contain very strong hardware safeguards for protecting portions of memory which must remain unaltered. The IBM 360/40, the MRS computer, can be ordered with certain safeguards, but their adequacy is doubtful.

Third, whenever an individual department makes use of a central computing facility, there occurs a loss of control over computing costs. The individual department is obliged to pay whatever portion of the computing "bill" the administrators of the central system define is theirs; it may be difficult for the department to check on whether the resources for which it is being billed were actually used or, indeed, whether they would have been required at all if the central facility's software was working properly.

Fourth, a good deal of overhead is incurred in any attempt to share a large central computing facility among several users. Essentially the large computer has to put away things in temporary storage locations in order to switch from one job to another. If the system is repeatedly interrupted for very small tasks, the result can be very severe loss of efficiency. Useful computing can decrease to as little as 12 to 15 percent of the operating of the time in some large time-shared computing installations because of these overhead problems.

Use of a Satellite Computer

Use of a satellite computer system would mean that the Radiology department would have its own computer system capable of handling its own local needs. It would be able, by a direct hookup, to communicate with the MRS computer in order to access the MRS patient-data base. As already indicated, we believe this approach is by far the most desirable. Initially, the satellite computer might be operated as a free-standing computer for a period until the hardware and software development on the MRS computer installation reaches the point where hookup is feasible.

The only disadvantage of apparent consequence with this approach is that when considering those obvious costs which can be estimated in advance, this approach looks more expensive than that of simply sharing the MRS computer. There is great likelihood, however, that the apparent cost advantage would disappear in the long run.

The advantages are:

- A satellite computer can be, both in hardware and in software, tailored to the needs of Radiology. There are many very inexpensive (under $50, 000 sale price for a system of probable adequacy) small real-time computers on the market, which in terms of gross arithmetic unit speed are not only closer to the 360/40 than one might think but, in many cases, actually surpass it on some types of problems.

- Not only would the Radiology department exercise control over the hardware from both a political and a cost viewpoint (to an extent quite impossible through sharing the MRS computer), but, and most important, the Radiology department could freely experiment with hardware hookups and software configurations. This could be done without any risk of destroying irreplaceable computer-media medical records or of disturbing operating background medical-record programs and interfering with the operating of the main center.

- Data would flow both ways. Data called out from the X-ray reports prepared on the Radiology department computer could be transmitted to the MRS computer for either entry into files or for forwarding to various departments for accounting and billing purposes.

- Because the satellite computer would be able to access the main data base in the mass memories of the MRS computer, it would need a substantially smaller mass memory than would otherwise be true. In addition it may not require as many different types of peripheral equipment because that of the MRS computer could, in many cases, be shared.

Use of a Stand-Alone Computer

This approach would be a second choice after the satellite computer. In actual practice, the satellite computer might be operated in this mode at first. The problems are that the Radiology department would have to achieve an independent (and parallel in many respects) data base to be able to satisfy its immediate and future needs. The larger data base would require both larger core memory for input-output purposes and more mass-memory-type peripheral units.

In addition to the greater memory capacity required, another factor leading to greater cost for the total system would arise because of duplication of other hardware and of software effort in accomplishing for Radiology many of the things which will in parallel be done with the MRS computer.

If there were no communications link between the Radiology department's computer and the MRS computer, accessing patient data in the MRS data bank would have to be done through an MRS terminal in Radiology. This data would then have to be manually entered in Radiology's computer which would be quite inconvenient. Data transfer from Radiology to the MRS system would be similarly inconvenient.

The advantage of the stand-alone computer is, of course, complete autonomy by the Radiology department. However, we believe that the degree of autonomy available with the satellite-computer approach would be satisfactory. The only points at which the satellite configuration would be subject to the control of the MRS authorities would be in defining the characteristics of the communication link and the manner in which requests might be made for data from the data base. This ought not to be a severe problem. There would, for instance, be absolutely no requirements that Radiology must use an IBM computer just because the Medical Record System does. In fact, IBM is likely to be one of the least satisfactory vendors for a small, low-cost, high-speed, reliable, real-time computer of the sort most appropriate here.

Use of an External Time-Sharing Service

This alternative is another which may be proposed by those whose major concern is cost. Indeed, for many users, it is a good alternative since in many situations it brings computing power to bear on a problem in the exact quantity needed for only as long as it is needed. However, there would be severe problems, not arising for many other typical users, if the MGH Radiology department tried to make use of an external time-sharing service.

First, all information must go to and from the time-sharing service over a data link, typically a 300 bit-per-second telephone line, unless permanent hardwired connections are installed. A leased line would raise this rate to 2400 bits per second which may still not be fast enough for some applications involving display on the face of a CRT terminal.

Second, the Radiology department would have absolutely no control over the operation of the CPU. Down time might destroy some of the Radiology records if a disc file failed at the time-sharing service house; they might, in addition, be unable to use the system at all during critical times if the CPU failed. In addition, there would be no control at all over costs. Pricing schedules for these services range from very simple (in which one only pays by the hour for use of a terminal) to very complex (in which one pays a charge depending on the average amount of core or mass memory space used during a month and in addition pay a charge for CPU time, tape time, etc.). Moreover, it could be nearly impossible for the Radiology department to check on whether these charges are both just and correct or, if they are, whether a significant portion of them may not be due to inadequately or ineptly designed software.

Last, and possibly most important, the Radiology department could be in violation of Massachusetts law relating to the confidentiality of certain patient's medical data (ref. 14). X-rays may in some cases be evidence of occupationally induced illness or of on-the-job accidents, and both of these categories of information are accorded very special protections under Massachusetts law (ref. 14, Table 1, p. 245). It is not clear at present if the Radiology department would be fulfilling its legal obligations to keep such information private if it were stored off-premises in a mass memory at a time-sharing service house -- particularly if that house were located outside the borders of Massachusetts, as is quite likely.

APPENDIX J
SYNTAX ANALYSIS FOR RECEDE, CEDE, AND DITRIDE

APPENDIX J

SYNTAX ANALYSIS FOR RECEDE, CEDE, AND DITRIDE

INTRODUCTION

Of the six approaches to radiological reporting discussed in Section 7.4, one (MUCHBRA) builds up sentences out of words by methods which inherently allow the generation only of easily analyzed syntax; one (KUFT) requires keywording by the radiologist, thus eliminating, at least for the present, the requirement of automatic keywording by the computer software; one (UFT) eliminates the problem (and the benefits of solving it) by foregoing keywording altogether; and three (RECEDE, CEDE, and DITRIDE) let the radiologist say anything he wishes, subject to "syntactic constraints" which are not spelled out in 7.4. These are discussed in this appendix.

Syntactic Ambiguities

Allowing the use of unrestricted, full-flower English sentences would raise nasty technical problems of syntax ambiguity. It is not well understood yet just how human beings comprehend spoken languages. Moreover, English is one of the least logical of widely-spoken tongues, particularly because so much of the meaning of a word derives from its context and its position in the sentence. Thus, to quote two well-known examples, "blind venetian" and "venetian blind" do not mean the same thing, and "half baked chicken" can be parsed to mean "partially cooked chicken" or "one-half of a baked chicken". Another example more pertinent to medicine is the word "cut", which can be a noun ("a small transverse cut"), a verb ("the surgeon cut the skin graft from the back"), or an adjective ("the cut finger did not become infected").

Why Use Syntactic Constraints?

The proposed syntactic constraints are properly understood as an engineering compromise. A brief survey of the literature (ref. 30-32) indicates that, whereas it would be too much to promise that software for analyzing unrestricted English could be developed in time to be useful for the proposed system this time around, the prospect of developing software to analyze a restricted set of English is eminently reasonable. After all, one very convincing example of this approach -- COBOL compilation in the business computation world -- is in widespread use at present.

The syntax constraints proposed here would not necessarily make the resulting text awkward to read; the reader would not be encumbered with anything out of the ordinary. In fact, COBOL programs can be quite readable if programmers put in a little effort to make them be so, although all COBOL programs are not necessarily readable.

The purpose of these constraints is to cut the problem of parsing the radiological report by computer down to size. Only some operating experience with them would fully indicate whether they are just about as strong as necessary, or too strong, or too weak. Hopefully, future improvements in syntax analysis technique would allow the restrictions to be eased one by one.

DESCRIPTION OF SYNTACTIC CONSTRAINTS

The following outline covers three types of constraints: a report format, cues, and restrictions.

The format is no more burdensome than the standard ones now in use. The computer system would require an entry under each heading, but that entry could be "NONE" in some cases.

The cues are intended to enable the computer to parse sentences in the report. The idea of such cues is not new (ref. 30 describes some similar ones), but this approach apparently has not been applied previously to radiological reporting. As the report is entered by the radiologist (RECEDE or CEDE) or by the medical secretary (DITRIDE), the software would attempt to insert these cues in such a way as to completely fix the meaning of the sentence. Where it could not do so, the person at the keyboard would be so informed and would be requested to enter them, using a cursor or some similar technique.

The restrictions are simply a set of ad hoc rules intended to eliminate troublesome situations which could otherwise cost a good deal of computer decision-making time.

Figures J1 and J2 show the same radiological report, as it was originally generated at Massachusetts General Hospital and after being reworked to conform to the restrictions and include the cues. The cues would not be printed out the way they are in Figure J2 except where such a printout was specifically requested.

Report Format

There are six headings in the body of every report (after patient data, etc.). They are all mandatory although "NONE" may appear after some of them. They are:

Area Examined
Procedure
Findings
Impression
Qualifications
Follow-up Examinations

PATIENT DATA:

UNIT NO.
NAME
FLOOR, CLINIC OR ADDRESS
AGE
SEX

EXAM DATE 3/30/67

AP AND LATERAL CHEST

THE BONES OF THE THORAX SHOW DEFORMITIES OF THE RIGHT RIB CAGE CONSISTENT WITH OLD FRACTURES. NO NEW FRACTURES ARE IDENTIFIED. THERE IS A SLIGHT INCREASE IN LUNG MARKINGS AT BOTH BASES CONSISTENT WITH CHRONIC CHANGES. THERE IS AN IRREGULAR POORLY DEFINED DENSITY SEEN IN THE MID-LEFT LUNG FIELD SUPERIMPOSED ON THE SEVENTH RIB POSTERIORLY WHICH MAY BE PARTIALLY ARTIFACTUAL DUE TO A RIB END, BUT A REPEAT FILM AND AN OBLIQUE FILM IS INDICATED. THE HEART AND MEDIASTINUM APPEAR ESSENTIALLY WITHIN NORMAL LIMITS.

IMPRESSION: QUESTIONED DENSITY IN THE LEFT MID-LUNG FIELD THE NATURE OF WHICH IS NOT CLEAR, BUT THIS COULD BE EVALUATED ON A REPEAT FILM AND AN OBLIQUE FILM.

Figure J1. Typical Diagnostic Report

PATIENT DATA:

Unit Number
Name
Floor, Clinic, Address
Age
Sex

EXAM DATE: 3/30/67

/H **AREA EXAMINED:** Chest

/H **PROCEDURE:** AP X-Ray: Left Lateral X-Ray

/H **FINDINGS:** /S The bones of the thorax /V show /O deformities /OM of the right rib cage /OM consistent with old fractures. /S New fractures /V are not /O identified. /S Lung markings /SM at both bases /SM consistent with chronic changes /V have increased /VM slightly. /EV There is /S an irregular density, /SM poorly defined, /VM in the mid-left lung field /VM posteriorly superimposed on the #7 rib. /S This density /V may be /OM partly artifactual /OM due to a rib end. /V Repeat this X-ray; oblique X-ray. /S The heart and mediastinum /V are /OM essentially within normal limits.

/H **QUALIFICATIONS:** /S This density /V may be /O artifactual.

/H **IMPRESSIONS:** /S Density /SM in the left mid-lung field /SM of undetermined nature /V is seen.

/H **FOLLOW UP EXAMINATIONS:** /V Repeat /O AP X-Ray; /V Repeat /O Left Lateral X-Ray; /O Oblique X-Ray

ADDITIONAL: Rib Detail X-Ray; Left Posterior View

Figure J2. Structured Verse Diagnostic Report

Cues

Cue	Meaning	Verbal Abbreviation
/S	subject	"sub"
/SM	subject modifier	"sub mod"
/V	verb	"verb"
/VM	verb modifier	"verb mod"
/O	object	"ob"
/OM	object modifier	"ob mod"
/EV	existence verb at beginning of sentence	"ex verb"
/H	heading	"heading"
/F	radiological follow-up to be done	"follow-up"

Restrictions

Only two types of sentences are permitted:

(subject) - (verb) - (object); object is optional

(existence-verb) - (object)

No compound sentences; begin a new sentence rather than using "and", and begin a new sentence with "however" or a synonym rather than using "but".

No words, such as adverbs, are permitted between portions of compound verbs. Thus, "may be seen readily" is permissible, but "may be readily seen" is not.

Only verbs can be negated -- not nouns. Thus "there are not any lymphomas" is permissible, but "there are no lymphomas" is not.

The only allowable way to express the genitive case is with "of". Thus "the wall of the chest" is permissible, but "the chest wall" is not unless "chest wall" happens to be a dictionary entry in its own right. "The chest's wall" is in no case permissible. Nouns in apposition, such as "chest" in "the chest wall" are not permitted except as noted.

Single-word modifiers of a noun or verb normally precede it. There can be more than one, but they must be adjectives or adverbs and not nouns in apposition. Phrases and single words which modify a noun or verb must follow it, and must be preceded with the cue "/XM" where the X is S, V, or O.

The headings "Area Examined", "Procedure", and "Follow-up Examinations" permit only lists of nouns separated by semicolons, with no cues required. The headings "Findings", "Impressions", and "Qualifications" permit prose but require the use of cues.

The cue /F (follow-up examination) likewise permits only lists of nouns separated by semicolons, with no cues required.

All lists must repeat items in full. Thus, in the text, "/O the right lung, the left lung, and the spleen" is permissible, but "/O the right and left lungs and the spleen" is not. Each item in the list must be set off by a comma in prose or by a semicolon for those headings which permit only lists.

A period is interpreted as teminating a sentence. It voids the cue /F for subsequent words, and a new sentence or else /H is anticipated to follow it.

"NONE" exactly as shown can be used after any heading without any cue being necessary.

The period after the list (or after "NONE") following the subheading "Additional", under the heading "Follow-up Examinations", terminates the report.

239 verso blank

APPENDIX K
A WORD-COMPLETION TECHNIQUE FOR RECEDE

APPENDIX K

A WORD-COMPLETION TECHNIQUE FOR RECEDE

The RECEDE approach to automated radiological reporting was derived by adding several conveniences to the CEDE approach to eliminate as much typing as possible. These conveniences include MUCHBRA-type graphics, lists of standard sentences, a dense-coded keyboard (see Figure K1) for certain very commonly used words, and the word-completion scheme to be described here. This word completion scheme is believed to be unique, among techniques proposed for automated radiological reporting, in that it organizes words according to their verbal properties instead of according to their contextual or subject-matter properties. It is presented partly for its own sake, and partly because it may be suggestive of other worth-while approaches. To be sure, reference 16 does describe an earlier radiological reporting system using portions of words, although in a different way, to obtain full words.

It is assumed that the computer controlling the report-generation displays has access to an on-line dictionary containing all words, both radiological terms and ordinary English, which can occur in radiological reports generated on-line. If this dictionary is somewhat large in relation to the available high-speed memory capacity, some of the sophisticated file-organization techniques described in reference 29 may be appropriate. Since some recent theoretical work has apparently solved some of the difficulties in handling a number of different terms all of which have the same root form (ref. 17, 31), perhaps only root forms need to be maintained in the dictionary. Any competent radiologist should be allowed to update the dictionary, as in some other approaches (ref. 16).

For searching purposes, the words are stored in a sequential list in such a way that the position of a word in the list provides a pointer to any other information which the dictionary must contain about that word (see again ref. 29). The order of the words in the list is lexicographic, or standard "dictionary order". If the radiologist wishes to use the word-completion features of the system what he must do is to type the first n letters of the word (typically n = 2, 3, or 4) at the alphanumeric keyboard, and then depress the "complete word" key on the dense-coded keyboard (Figure K1). A display is then generated of the letters he typed followed by the balance of each word from the dictionary whose first n letters are identical to those typed. If desired, these possible endings for the word can be made to "roll" slowly by the first n letters. When the proper ending is lined up, the radiologist again depresses the "complete word" key, and the word is entered in his partially composed message. The three letters CAR might, for instance, correspond to eleven possible words in the dictionary such that, after the first three had rolled by, the word-conpletion display would appear as follows:

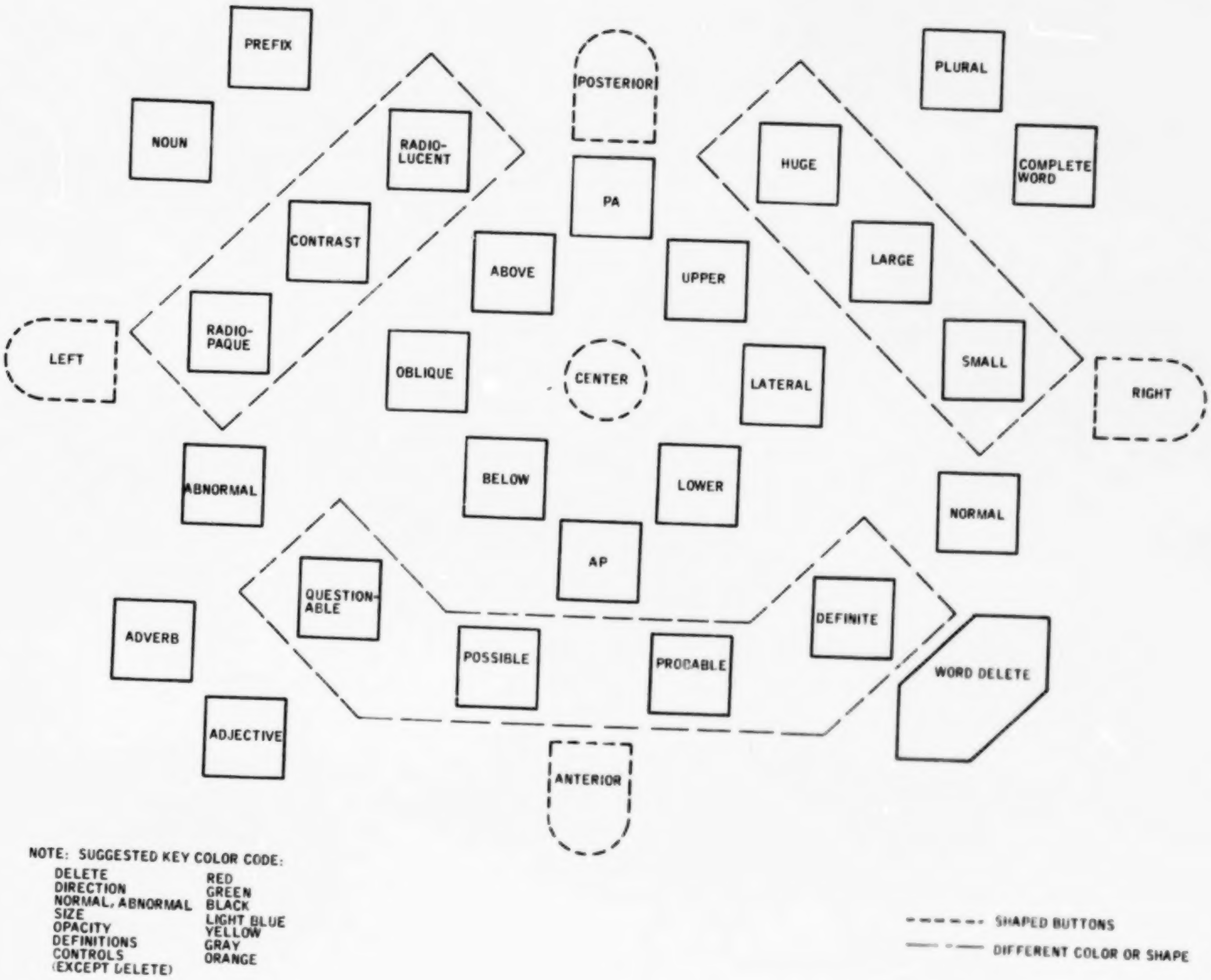
PREFIX
NOUN
RADIO-LUCENT
POSTERIOR
PLURAL
HUGE
COMPLETE WORD
PA
CONTRAST
ABOVE
UPPER
LARGE
LEFT
RADIO-PAQUE
OBLIQUE
CENTER
LATERAL
SMALL
RIGHT
ABNORMAL
BELOW
LOWER
NORMAL
AP
QUESTION-ABLE
DEFINITE
ADVERB
POSSIBLE
PROBABLE
WORD DELETE
ADJECTIVE
ANTERIOR
NOTE: SUGGESTED KEY COLOR CODE:
DELETE RED
DIRECTION GREEN
NORMAL, ABNORMAL BLACK
SIZE LIGHT BLUE
OPACITY YELLOW
DEFINITIONS GRAY
CONTROLS (EXCEPT DELETE) ORANGE
SHAPED BUTTONS
DIFFERENT COLOR OR SHAPE

Figure K1. 32-Code Supplementary Radiological Dense-Coded Keyboard

BON
BUNCLE
CINOMA
CAR DIAC
IES ↑ Direction of roll
INA
NOSITY
OTID
PAL
PUS
TILAGE

Just in case the radiologist did not move quickly enough to select the ending he desired, the list of endings would roll by a second time if he had not made a selection after the first pass.

If the radiologist wished to enter the word "carcinoma" according to this technique, and the above set of dictionary entries for the first three letters CAR were the complete set, it is evident that he would save time by entering the first four letters "CARC" instead of merely "CAR". Conversely, entering merely the letters "CA" would be poor strategy, since the complete list would take a long time to roll by. Hence, there is a minimum-labor strategy for constructing any given word, and in time any radiologist using this system would learn that strategy for the words he tended to use the most. It may not be altogether fortunate that the scheme puts this kind of premium on "maze-learning aptitude," but there would be great benefits for any radiologist adequately endowed with this aptitude.

It is evident that there are two classes of keys on the dense-coded keyboard of Figure K1, those which enter information directly (e.g., "AP," "lateral," etc.) and those which are "operator" keys operating on information already entered ("complete word," "adjective," "delete," etc.). All of the keys in the central diamond pattern are of the first type, and those at the corners outside that pattern are of the second type. A few examples will illustrate the use of these operator keys. For instance, having constructed the word "CARCINOMA," the radiologist can get the word "CARCINOMATOUS" merely by depressing the "adjective" key, and if for some reason he wishes to use the word "CARCINOMATOUSNESS" he can then get that by next depressing the "noun" key. Other combinations of operations indicated by the keyboard will also produce the logically expected result; for instance, depressing the "AP" key and then the "adverb" key yields "anterioposteriorly," and the definite key followed by the "noun" key yields "definiteness." The word

2 44

K4
mc

"CORTICO-STEROID" could be formed as follows: first obtain "CORTEX" by word-completion, then depress the "prefix" key, and then obtain the word "STEROID" by word-completion.